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ENVIRONMENT PROTECTION IN THE PRODUCTION AND USE OF ENERGY[x]

BY

Yehia Elmahgary Dr. Techn

x The views expressed in this paper are those of the author and are not necessarily those of United Nations.

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INTRODUCTION

At local, national and in some cases regional levels, the environmental aspects of energy production and use have become the subject of wide-ranging debate. Environmental awareness and anti-pollution campaigns have affected the formulation of energy policies in many countries, and it has recently been realised that nations are not isolated in this respect: the actions of one country may affect the environment in a neighbouring one. Nowadays, energy policy decisions are dictated less by technological than by social, environmental and political factors.

The production, transportation and use of different sources of energy raise a number of important environmental issues. Among these, questions of the availability and allocation of resources are likely to play as important a role as pollution problems proper. Land and water use, emissions (including thermal discharges) and their impact on ecosystems and human health are but examples of the problems encountered. The 1970's, brought into focus some related socio-economic and geo-political problems. For example, nuclear power development raises problems related to ultimate disposition of nuclear wastes, possibilities of diversion of nuclear material for military purpose or terrorists action and to the public acceptance of this source of energy. On the other hand, concern has been recently voiced at the implications of extensive coal utilization, especially its possible impact on climate. The atmosphere is believed to show a warming due to increasing carbon dioxide emissions. The important question is: what will the regional changes of temperature and rainfall be? Studies with climate models and of climate observations indicate that regional anomalies will probably occur, but the magnitude and impact of these anomalies cannot be reliably predicted at present. The medium and long-term effects of such possible climatic changes are of such fundamental importance that they command serious attention.

The general realization of the finite nature of fossil fuel resources has caused a re-examination of the possibility of using those energy resources which are of a non-depleting nature, and are therefore considered renewable. These energy sources are becoming increasingly important both in developed and in developing countries. In the former strategies for the exploitation of such sources constitute a part of recent policies which aim at reducing the dependence on fossil fuel. In the developing countries, particularly those short of fossil fuel resources, the renewable sources of energy show promise of meeting some of the future energy needs especially of rural areas. Without strong rural development programmes based on decentralized energy sources, urban migration will become torrential, exacerbating the already dire urban problems.

UNEP's pioneer work in the environmental impacts of the production and use of energy has shed a lot of light on this subject, created awareness about environment protection and stimulated interest on the development of tools and methods to control the emissions and releases of the different energy cycles.

In the present paper the environmental impacts of the production and use of energy will not be discussed, instead the emissions and releases of the energy cycles will be summarized. This will be followed by a detail discussion of the methods of controlling these emissions and releases for the ultimate goal of protecting the environment.

In order to facilitate comparison and for convenience the fuel cycles will be divided into stages viz, extraction, transformation, processing, conversion and waste handling. The fuel cycles that are going to be considered here are those used currently or to be used in the near future in developing country particularly in Africa. These are coal, oil, natural gas, nuclear, fuelwood, geothermal, hydropower, wind, solar and biogas.

I. FUEL EXTRACTION

The emissions, releases and occupational health hazards of the extraction stage of different facts are summarized in Table 1. The estimated land and water used are also given in the same table for the production of one TWeh. The reference systems and the other detailed assumptions as the plant size, type and life are in UNEP 1985.

In the following the environmental control of the main emissions and releases of different fuel extraction processes will be discussed.

A. FOSSIL FUELS

1. Coal

Many environmental impacts of coal mining and preparation are unavoidable. For instance, short-term loss of wildlife habitat and agricultural production is inherent in surfact mining. In many instances effective application of existing control techniques and procedures will mitigate the impacts. New control technologies are needed mainly to allow productivity to be improved while meeting recognised environmental objectives.

(a) Airborne Emission Controls

Airborne emissions result from uncontrolled accidental burning of coal piles, refuse piles, and mines: from gases released from piles without burning; and from fugitive dust. Sources of fugitive dust include coal and overburden handling, drilling, blasting and wind erosion. Dust can be controlled during handling by spraying the coal with chemicals or water during loading and unloading, wetting haul roads, and covering haulage equipment. Cyclones and water sprays can be used with drills, and proper placement of explosive delays in blasting rounds can reduce dust by efficient fragmentation. Dust problems may be reduced by the use of electrostatic precipitators fabric

filters, or even well-designed buffer zones. Windbreak can effectively reduce visible dust emissions from wind erosion of coal and overburden.

Gaseous emissions may occur from accidental burning (possibly resulting from spontaneous combustion) and natural releases from refuse banks, mines, and coal piles. Fires can be prevented by controlling air circulation, the concentration of combustible material, and temperature. For preventing fires in abandoned mines, the best techniques including removing excess combustible material and sealing openings to reduce air circulation. Air can be eliminated from refuse piles by compacting and burying them.

(b) Liquid Effluent Controls

The potential sources of water pollution from conventional technologies of coal extraction and preparation are mine drainage, preparation-plant wastewater, and storm water runoff (including refuse and coal-pile leachate) There are several treatment alternatives that apply to all of these sources. although the technique selected and the degree of treatment required, depend on the level of contamination (US/DOE 1981).

Ideally, the best treatment for acid water is to inhibit its formation by preventing oxygen flow to the pyrites. Removing pillars so that the roof can colapse (where subsidence is acceptable) and backfilling and sealing the mine to reduce air flow are the most common ways to minimize acid drainage problems. Control of water flow is also helpful, but is not practical in most cases. There is no effective way to control acid formation in abandoned mines. Alternatives for treatment of mine drainage after its formation include the following (US/DOE 1979). Bcentel Corp 1977.

Chemical precipitation of dissolved solids (usually by pH adjustment).

* Aeration (spraying to entrain air)
* Removal of suspended solids (chemically, by flocculation, or natural settling in ponds)
* Neutralization (chemical pH adjustment)
* Filtration (naturally, through local soil)

Mine drainage is categorized as acid or alkaline. Acid mine drainage generally poses the more serious problem; it commonly requires extensive treatment. Alkaline mine drainage is actually neutral or slightly alkaline and is usually low in toxic metals. Alkaline mine drainage may require only settling to remove suspended solids, and often requires no treatment before discharge.

(c) Control of Water Usage

The two aspects of water usage of primary interest are water consumption by various mining activities and the impact of mining on surface water or ground-water supplies. Water consumption may be reduced by using mine water in the preparation plant, recycling preparation plant or slurry-pipeline water, substituting other liquids for water, and carefully controlling dust-generating activities so that wetting will be minimized.

(d) Land Use Controls

Land is affected by subsidence of underground mines, inadequate reclamation of surface mines, and improper waste disposal. Alternatives that may reduce subsidence impacts include, for example, leaving more or larger pillars, backgilling with preparation plant refuse, and promoting a more controlled subsidence through panel mining.

Inadequate reclamation of surface mine areas may result in the loss of important farmland or wildlife habitat. (US/DOE 1979(b)).

(e) Health and Safety Controls

Barring unforeseen technological advances that would significantly lower the number of miners in mines, the key occupational health and safety objective is improvements in the workplace. The most important of these are miner training, emphasis on safe working practices, and development of equipment that is safer in design and operation. The primary miner health and safety issues in underground mines are roof collapse, explosion and respiratory disease. (US/DOE 1979). Development of new types of equipment, or of safer designs for existing equipment, could lower the number of injuries and deaths. Coalbed methane venting practices may reduce the risk of explosion while simultaneously recovering a significant energy resource. Dust suppression and increased ventilation could reduce respiratory illness.

2. Oil and Gas

(a) Steam Generator Controls

Gaseous emissions from steam generators are the major problem requiring control technology; present controls are the same as those on many industrial and utility boilers today, or are adaptations of them. These will be discussed in details in Chapter IV.

(b) Water Treatment and Disposal

Water treatment may occur as the first step in injection and preparation or as the last step in treating produced water for reuse or disposal. Both produced and source waters can be treated by readily available methods including separators, coalescers, flotation/flocculation gravity separation and softening (Ref. Chapter IV).

Unexpected pollution of underground drinking-water sources by well stimulations can usually be prevented if subsurface stress conditions are identified during the planning stage. When the stress field near the stimulation zone is understood, fracture orientations can be estimated in advance. Such data, along with information on jointing, faulting and aquifer and confining-bed properties at the drilling sites, will prove invaluable for minimizing groundwater pollution.

Impacts from subsurface injection of geopressured brines will occur if injection strata are unsuitable. Careful monitoring of injection pressures, annulus pressures observation-well levels, and other parameters will allow rapid response if well casings unexpectedly fail or confining strata surrounding the injection zone are fractured. Apart from reinjection, the fluids may be treated and used as a source of useful chemicals, such as potassium chloride. Spills or accidental releases of brine in coastal areas could have a significant detrimental impact on wetlands and their ecosystems.

(c) Solid-Waste Disposal

Disposal of solid wastes from drilling operations poses no particular problems; existing landfill or surface distribution techniques may be used. The waste materials for the most part are rock, shale, sand, and clay, whose major environmental impact would be temporary sedimentation of surface waters. Proper grading, drainage and ground cover at the disposal site will keep this problem to acceptable levels. If drilling muds contain chemical or petroleum additives that would pollute surface waters the material can be removed from the site storage pit and reused at other drilling sites, or it can be placed in a "secure" landfill and covered or drained to prevent water infiltration (EPA 1973).

(d) Worker Health and Safety

The most effective mitigation measures for all the hazards of high-pressure and rotating machinery including fires and explosions during drilling and production is a combination of worker training and proper equipment design, which will minimize exposure. In addition, where new or particularly hazardous materials are in use, a program of worker and work environment monitoring could be initiated to measure routine worker exposure and to provide information on any health or safety problems identified.

B. NUCLEAR FUELS

1. Uranium Mining

Solution mining in which the ore is leached in situ from the underground deposit is sometimes practised, thereby alleviating the environmental problems as the need to move large quantities of material, radioactivity of the ore and the solubility of uranium in water (OECD 1984). By careful planning, design and operation of mining facilities and by maintaining adequate ventilation to protect miners from health hazards with radon and radon daughter build up and from dust (UNEP 1980) control of health hazards could be achieved.

2. Uranium Milling

After the uranium has been extracted, more than 90 per cent of the original activity in the ore and virtually all the radium-226 remains in the milling tails (US/DOE 1983). Special treatment of uranium mill tailings before disposal is required. The U. S. Nuclear Regulatory Commission (NRC 1979) has identified two main aims for central technology of mill tailings, viz, to limit release into the air of radon gas and radioactively contaminated particulates, and to limit the leaching of radion-uclides and toxic trace metals into groundwater or surface runoff.

During milling operations, emissions are controlled by keeping the tailings pile-covered with water and spraying dry areas with water or chemicals to form crusts on the surfaces. This reduces radon emanation and wind erosion of dust. NRC has evaluated several options for each of four interdependent aspects of tailings disposal: treatment, disposal location, tailings area preparation and tailings stabilization and isolating cover. Treatment variations identified may include nitric acid leaching to remove (or better isolate in a smaller volume) radium and thorium, separation of the small size fraction (slimes) that contains most of the radionuclides, neutralization or chemical treatment to precipitate radium, removal of nuclides by ion exchange, dewatering, and incorporation in asphalt or cement. Final disposal options include above-grade surface impoundments, open-pit mines, special below-grade excavations, or deep mines. The surface on which the tailings rest may be prepared either by compacting the soil or by using clay or synthetic liners to contain seepage. After emplacement, possible cover materials include (except for deep mines) soil, gravel, stone riprap, clay, or an artificial sealant like plastic or asphalt.

C. RENEWABLE ENERGY SOURCES

Environmental impacts are also associated with the extraction of new and renewable energy sources. Some could be controlled as the brine in the case of Geothermal energy which should be re-injected or disposed of adequately. Others have unavoidable impacts as the construction of dams in hydropwer and the use of land in fuelwood and biomass. Because the extraction and processing stages, if any, are usually in the case of new and renewable energy sources associated with the conversion stage this will be discussed in connection with the conversion stage (Chapter IV).

II. FUEL PROCESSING

The emissions, releases and occupational health hazards of fuel processing stage of different fuels are summarized in table 2. The figures are normalized for the production of TWeh. Following is a discussion on the environmental control aspects of this stage.

A. FOSSIL FUEL

1. Coal

The physical benefication techniques associated with coal cleaning are capable of removing up to 40-50 per cent of the sulfur and 65-75 per cent of the ash contained in the raw coal (Ferrel 1979).

(a) Airborne Effluents

Air pollutants created are fine coal dust, ash, NO_x and SO_x resulting from combustion of coal used to supply the hot gases for coal drying. Air pollution can also arise from burning of refuse piles at coal preparation plants which have caught fire as a result of spontaneous combustion. This can be avoided by preventing oxygen from reaching the carbonaceous material, by reshaping the pile to avoid steepy sides and by covering the pile with soil and vegetation (UNEP 1980).

(b) Liquid Effluents

The liqued effluent produced is called blackwater and contains suspended coal fines.

Black-water is usually sent to a tailings pond where the solids are allowed to settle and then clear water re-circulated. Closed water circuits

have grown in popularity because they eliminate discharge to streams and reduce make-up water.

(c) Solid Wastes

This consists of coarse and fine refuse. Pollution can be controlled by proper reclamation to prevent seepage and divert seepage from the piles to settling ponds where suspended solids and other pollutants can be retained and treated.

2. Oil and Gas

(a) Airborne Effluents

These consists mainly of SO_x, NO_x particulates, hydrocarbons and CO. The control of these emissions will be discussed in Chapter IV.

(b) Liquid Effluents

These wastes are readily treatable with a combination of in-plant controls and treatment techniques and end-of-pipe treatment (UNEP 1980). The last consists mainly of primary separation of oil and solids and neutralization, followed by biological treatment using activated sludge systems, aerated lagoons or oxidation pond.

B. NUCLEAR FUELS

Since nuclearfuel processing is being accomplished mainly in developed countries only brief methods of environmental control will be given below.

1. Uranium Hexafloride Production

In the hydroflour process, the final residue is packaged and buried as low activity solid wastes. In the wet process, the stream which may contain substantial disolved solids (radium-226, Thorium-230 and about 0.2 per cent of the uranium processed) is neutralized and imponded in a retention pond.

Disposal of this effluent is a major problem associated with the wet process. Scrubber effluents of both the hydroflour and wet processes are treated with lime to precipitate flouride in the settling ponds for packaging and burial as calcium fluoride.

2. Uranium Enrichment

The main airborne emissions of the uranium enrichment process are SO_x, NO_x, CO, HC, particulates and uranium-234, 235 and 238 nuclides. Methods of controlling this pollutants will be discussed in details in Chapter IV.

On the other hand the concentration of chemicals in the liquid effluent undergoes considerable dilution before reaching the receiver water (UNEP 1980).

3. Fuel Fabrication

(a) Airborne Effluents

Nearly all of the airborne chemical effluents result from the combustion of fossil fuels to produce electricity to operate the fabrication plant. This will be considered in Chapter IV. Apart from these pollutants flouride is the only significant chemical gas emission from the fabrication process. This could be effectively removed from the air effluent streams by scrubbing and filteration systems.

(b) Liquid Effluents

Nitrogen compounds, which is the most significant chemical species in liquid effluents, is combined with water from air scrubber systems and treated with lime to form a calcium fluorine precipitate which is filtered and stored on site.

The dose commitments to workers and public from fuel fabrication are very low and it is unlikely that the fuel fabrication activity would increase levels of exposure (UNSCEAR 1977).

C. RENEWABLE ENERGY SOURCES

Most of the new and renewable energy sources has no processing stage. Cycles with processing stages, such as biomass will be included in the conversion stage.

III. TRANSPORTATION OF FUELS

Table 3 shows the summary of the environmental impacts of fuel transportation.

A. FOSSIL FUELS

1. Coal

To reduce community disruption, delays and accidents from unit trains, grade separations or rerouting of track around populated areas are alternatives. Rerouting of track away from communities will also result in reduced noise exposure.

2. Oil

Marine transportation is the most important mean of transporting oil. There is a wide variety of marine ecosystems which could be affected by marine transportation of oil (UNEP 1980). The lethal effect of oil depend on its concentration and on the length of time an organism was exposed to it. When an oil spill occurs, several options exist to deal with it:

(a) Contain and remove it

(b) disperse it

(c) burn it

(d) leave it

(e) a combination of these.

Selection of the most suitable technique or techniques depends on the circumstances of each spill. Preventive measures are of course usually more effective.

3. Natural Gas

Natural gas is usually transported by pipelines

The potential environmental impacts of pipeline construction are well known. On the basis of the experience gained extensive body of requirements and regulatives has been developed and implemented in many countries. These include preliminary analysis and impact assessments, desirable construction standards (erosion control, etc.) and required operating standards and practices (pipeline safety etc.).

B. NUCLEAR FUEL

The most hazardous waste shipped by the commercial nuclear power industry is spent fuel. This material is transported in massive stainless-steel casks. Lead or depleted uranium is used to provide shielding from

penetrating radiation. Designs requirements are very severe. A cask must be able to withstand (1) a free fall from a height of about 10m onto an unyielding surface with the package landing in such a position as to do the most damage (2) a free fall from a height of 1m onto a in-diameter steel plunger long enough to do maximum damage with the package in the most vulnerable orientation (3) exposure for 30 min to a free reaching a temperature of at least 790°C and (4) total immersion in water for 8 hr. It must also be able to withstand the pressure of 15 m of water depth without any leakage. Those accident test conditions represent the damage that a package might incur in a severe transportation accident - for example, an accident in which a truck collides with a bridge pier, crashes through a guardrail rolls down a rockey embankment and falls into a river: or an accident in which a train derails, railcars tumble around, several tank cars catch fire a propane tank car explodes, and firemen pumps water into the burning debris (US/DOE 1977).

C. RENEWABLE SOURCES OF ENERGY

Transportation of fuelwood may impost similar a health hazards as those of coal transportation hence similar environmental control measures should be valid for fuelwood.

IV. CONVERSION TO ELECTRICITY

The summary of the emissions, releases and health hazards of the conversion process is given in Table 4 for the production of TWeh. The environmental control aspects of this stage is given below in some details.

A. FOSSIL FUELS

1. Airborne Emissions

(a) Particulate Control

Particulate emissions are controlled with electrostatic precipitators baghouses and scrubbers. Electrostatic precipitators have been used for particulate control in coal-fired boiler applications for over 40 years but baghouses are now being considered for small boilers, low-sulfur coal applications and possible future applications in which a 10 per cent capacity limit must be met. Conventional scrubbers are less attractive economically because of high operating (energy) costs (US/DOE (1978). Electrostatic precipitators collect over 90 per cent of the fly ash in flue gas. The use of baghouses (fabric filters) has received recent attention for low-sulfur-coal applications, for which electrostatic precipators are less efficient. Performance data are limited but baghouses are generally considered to be over

99 per cent efficient. A third method is wet scrubbing, which may be used for the removal of particles alone but is more commonly used for removal of both particles and sulfur dioxides.

(b) Sulfur Dioxide Control

The principle of operation of a lime/limestone flue gas desulfurizing system is that sulfur dioxide is absorbed and reacts with dissolved alkaline species from limestone or lime. The reaction product, calcium sulfite or sulfate, is separated as a wet sludge that must be dewatered and further treated to stabilize it before it can be disposed of. Lime limestone systems can remove more than 90 per cent of the sulfur dioxide. Greater efficiency can be obtained with additives such as magnesium oxide and organic acides. One advantage of this process is that more than 90 per cent of the particles are also removed.

A second throwaway process currently in use is the sodium alkali process. It uses either dry sodium alkali or a wet scrubbing solution. The wet process uses sodium hydroxide, sodium carbonate, or sodium bicarbonate in a wet scrubber or spray dryer: the dry process uses sodium bicarbonate alone or with sodium carbonate. Wet scrubbing is up to 99 per cent efficient, and dry scrubbing is 60 to 95 per cent efficient, depending on the temperature of the alkali and the sulfur dioxide and how long they are in contact. Both processes are simple and use little energy.

The major disadvantage is the disposal of waste products, which are high in sodium salts. (De Vitt et al 1980).

(c) Nitrogen Oxide Control

The oxidation of nitrogen compounds in the coal products "fuel nitrogen oxides", which account for 50 to 90 per cent of the total nitrogen oxides produced by coal combustion. Most of the advanced combustion concepts and modification techniques are directed toward preventing the formation of fuel nitrogen oxides. A fuel-rich initial combustion zone is established in which the fuel nitrogen can be oxidized to molecular nitrogen, rather than to nitric oxide. Thus, all of the combustion modification techniques except flue gas recirculation (FGR) depend on reducing the availability of oxygen in the primary combustion zones.

Combustion modification techniques such as low excess air firing and staged combustion have been shown to be effective in reducing nitrogen oxide emissions from coal combustion. In low excess air firing, the unit operates at a reduced level of total comoustion air flow while maintaining acceptable flame and furnace conditions. There are three methods of staged combustion:

* Biased or off-stoichiometric firing: the air/fuel mixture in the boiler is stratified and part of the combustion air is diverted outside of the initial fuel/air mixing zone.

* Burner-out-of-service operations: the fuel flow to an individual burner is out (while maintaining the air flow)

* Overfire air ports: part of the combustion air enters by ports above the burner to generate fuel-rich conditions at the burner.

In flue gas recirculation, gas is taken from the exhaust stream and re-introduced in the furnace. This technique has often been used for steam temperature control: however, few coal-fired units use flue gas recirucla-tion (Martin et al 1974).

Both nitrogen oxide production and the effect of combustion modifica-tions in reducing it depend on how the furnace is fired. While modification techniques can significantly reduce nitrogen oxide emissions, more advanced concepts, such as new burner designs (which can be retrofitted onto existing units) or flue gas treatment, are required to achieve very low levels of nitrogen oxides.

2. Water Pollution Controls

Wastewater handling and treatment practices vary from plant to plant. They depend on local regulations and are closely tied to solidwaste handling practice.

(a) Cooling-Tower Blowdown and Once-Through Cooling-Water Discharges

Thermal pollution caused by the discharge of once-through cooling water directly to a receiving stream is another area of concern. It can be re-duced by the use of "helper" systems, which remove a portion of the heat before the effluent is discharged. Two examples are long discharge canals and ponds with floating powered spray modules (El Mahgary (1971)). The problem can be eliminated altogether by the use of closed (recirculating) systems employing cooling towers or ponds. Removing dissolved solids from wastewater is difficult. One potential treatment for controlling them is lime precipitation/sedimentation which is effective in removing chromium and zinc. The disadvantages of this process are an increase in the hardness of the water, scale formation on plant equipment, difficulties in dewatering or disposing of resulting sludge and a slow reaction of the lime.

(b) Controls for Water Discharged from Solids-Handling Operations

Pond overflow-water discharged from solids-separation devices, and blowdown or discharge from sluicing operations can contain suspended solids, dissolved heavy metals and trace elements, extremely acid or alkaline mate-rial, and occasionally oil and grease. Control methods include direct treatment (such as sedimentation, chemical precipitation and neutralization)

and process changes. Two process changes that eliminate large-volume discharges from once-through wet-ash handling operations are (1) retrofit dry fly ash handling and (2) closed-cycle buttom-ash sluicing. These ash-handling methods are discussed in detail under solid-waste handling and control.

(c) Controls for Metal Cleaning Wastes

Because metal-cleaning wastes are generated only periodically, many plants have them removed by a contractor. Another common practice is to discharge them to an ash pond. Incineration or evaporation of metal-cleaning wastes has increased since its commercial application in 1971.

3. Solid-Waste Controls

As described earlier; the significant solid waste streams from a fossil fuel power plant include fly ash, bottom ash and flue gas desulfurizing sludge.

(a) Handling, Disposal and Utilization of Fly Ash

Both wet and dry methods are used for collecting and disposing of fly ash. It may be collected dry with electrostatic preciptors or baghouses: disposal may be direct, or the fly ash may be added to scrubber sludge to stabilize it. If the fly ash is collected with a wet-collection device such as a venturi scrubber, it is pumped to a pond in slurry form or sluiced with scrubber sludge to a pond (US/DOE 1980).

One of the difficulties that may arise from disposal of fly ash in ponds or land-fills is the leaching of soluble alkali metal salts and trace elements into groundwater and surface waters. Leaching can be managed by proper site selection, such as avoidance of groundwater, and by careful monitoring and the use of pond liners.

The commercial use of fly ash in USA increased from 7.9 per cent in 1966 to 17.5 per cent in 1978. Fly ash is mainly used as a partial replacement for cement in concrete and as an aggregate material in road base and sub-base construction (US/DOE 1980).

(b) Handling and Disposal of Bottom Ash

In general, the ponding and landfill practices and costs described for fly ash are applicable to bottom ash as well. However, unlike fly ash, bottom ash normally does not leach, so ponds used for bottom ash alone do not require lining.

Bottom-ash sluicing/dewatering systems, as well as pond systems, can be operated in a "closed-cycle" configuration in which ash sluice water is sent to collecting hoppers for reuse in sluicing.

(c) Disposal of Flue gas Desulfurizing Scrubber Sludge

The options for flue gas desulfurizing scrubber sludge disposal include direct ponding and de-watering followed by landfilling. In either method, the sludge can be mixed with fly ash, fly ash and lime, or other materials used in commercial fixation processes. If the sludge is predominantly sulfite, it can be oxidized to gypsum before ponding or de-watering. In the case of mixed fly ash and scrubber sludge from a combined particulate and sulfur dioxide scrubber, the options for disposal are ponding, dewatering and fixation followed by ponding or landfilling, (US/DOE 2980). Scrubber slurries can be made into harder, more stable materials by physical treatment (compaction and moisture content control) and chemical treatment (addition of lime, fly ash, or other fixation chemicals).

B. NUCLEAR CYCLE

The discussion in this section will be limited to LWR power plants.

1. Gaseous Radiological Waste Control Systems

The principal source of gaseous radwaste in a BWR during normal plant operation is the noncondensable gas (some of which is radioactive) removed by air ejectors from the main steam condenser. The noncondensable gas is also a source of radiocativity in a PWR when there are leaks in the steam generators. Most gaseous radwaste in a PWR arises from the stripping of (1) the stream of coolant from the primary coolant system to the chemical volume and control system and (2) a coolant bleed to the boron control system. In modern plants, these gases flow through some or all of the following processes to minimize the release of radioactive effluents to the environment (Ron 1976).

* Catalytic recombination of hydrogen and oxygen to form water, which is treated by the liquid radwaste system.

* Delay systems that hold up release of noble gases to allow the short-lived isotopes to decay. Some BWRs use cryogenic distillation systems to separate the noble gases for longer storage.

* Charcoal beds, which adsorb radioactive iodine

* Filters, which remove particulates from the gaseous waste streams.

Other sources of radioactive gases that could be released into the environment from both PWRs and BWRs include valve-packing leaks, pump seal leaks, tank leaks and spills, and spent-fuel-pool gases that escape into the buildings. The

ventilation systems in the containment, radiological waste and auxiliary/fuel buildings are monitored and provided with particulate filters and charcoal adsorption beds. Figures 1 and 2 show typical gaseous radwaste processing systems in a modern nuclear plant (US/DOE 1981).

2. Nuclear Radiological Waste Control Systems

Liquid radwastes at both BWRs and PWRs may be classified as clean (low chemical content) dirty (moderate chemical content), chemical, and laundry wastes. The primary sources of these wastes are summarized as follows (Eichholz 1976).

Clean	Collected equipment drains, Valve and Flange Leakage, Pump seal leakage
Dirty	Floor drains
Chemical	Steam-generator blowdown (PWRs) Laboratory drains Borated reactor coolant (PWRs) Demineralizer-regenerant wastes
Laundry	Detergent wastes from laundries and shower drains

Other than laundry wastes, which have very low activity and are generally discharged directly to the environment after processing, liquid radwastes at modern power plants are reused as makeup water after being processed through one or more of the following effluent treatment systems:

(a) **Demineralizers (ion exchangers).** Demineralizers contain beds of chemically active resin beads that remove ions from solution. The efficiency of ion-exchange treatment of waste streams depends, among other factors, on the type and composition of the liquid, type of exchanger, regeneration method, radionuclides present, type of resin and operating procedures used. Only relatively clean waste can be processed in an ion exchanger because bed exhaustion occurs rapidly for liquids with a high concentration of total dissolved solids.

(b) Evaporators. Evaporators may be used in the dirty and chemical waste streams to concentrate the suspended solids by boiling off the water, leaving behind most of the dissolved and suspended solids. Wastes high in dissolved solids are best processed by this method.

(c) Liquid Filters. Filters are used to remove suspended particulates from relatively clean liquid waste streams. They are employed with other types of waste treatments as a necessary post or pretreatment step in the liquid processing so that other steps will be more effective.

(d) Holdup Storage. Since many radionuclides in liquid wastes have short half-lives they are stored in large tanks for up to several weeks to permit as much decay as possible.

(e) Reverse Osmosis. In osmosis, water flowsfrom a region of low chemical concentration through a permeable membrane into a region of higher concentration, tending to equalize concentrations on both sides. If a reverse force exceeding the osmotic pressure is applied to the high-concentration side, reverse osmosis occurs. This process is used to purify some laundry wastes and to treat some PWR steam-generator blowdown.

(f) Oil Separators. Oil separators are used to remove the oil and grease from dirty waste streams prior to radwaste processing.

From the foregoing discussions of the various liquid radwaste control processes it is evident that no single method is adequate to provide the high purification required before wastewaters can be reused as makeup water or discharged to the environment. In practice, therefore, combinations of methods are employed.

3. Nonradwaste Effluent Control Systems

Chemical and other nonradioactive wastes, such as materials for corrosion control, may have a greater environmental impact than the low-level radioactive material released into the plant's liquid discharge line. This is particularly so in modern plants, which add and concentrate various chemicals in the closed cooling systems. From these, a small fraction of chemical-laden coolant is drained off (blow down) to limit the buildup of chemicals. Some of the various chemical wastes require removal, but most of them are simply diluted and released to the river in concentrations that meet local water-quality standards. Various removal methods, which are employed on a case-by-case basis are: (Eichholz 1976).

(a) Settling Ponds. If blowdown from the cooling towers, makeup water treatment building, or other sources contains a high concentration of suspended material that would exceed local water quality standards, it may be diverted to a pond or basin to allow the solids to settle before being discharged to the local surface waters.

(b) Neutralization Basins. In these basins, waste liquids that are excessively basic or acidic (e.g. demineralizer regenerant wastes) are combined with other chemicals to neutralize them before they are discharged to the local surface waters.

(c) Oil Separators. Liquids drained from the turbine building, the diesel generator building, and other sources that may collect oil or grease are sent through oil separators before being discharged to the common yard sewer drains.

(d) Sewage Treatment Plant. Lavatory and sanitary drain flow is treated in a sewage treatment plant before being discharged.

(e) Cooling Ponds or Towers. Cooling ponds and towers are used to disperse the majority of the thermal heat discharged from the power plant through evaporation, so as to largely avoid the thermal pollution of the surface waters that might be caused by once-through cooling systems. Cooling ponds are used when land is available at a moderate price, since they occupy about 400...800 ha/GWe of installed capacity. When land is not readily available, cooling towers are used. Cooling towers are classified as either wet or dry; in wet cooling towers, heat is disipated by the evaporation of some of the water being cooled: in dry cooling towers, heat is transferred by the flow of air across pipes containing the water. At present, only wet cooling towers are in use at nuclear power plants. Cooling towers are also classified by the means of producing the air flow: This can be a mechanically induced draft, using large fans, or a natural draft, using a tall usually hyperbolic "chimney" to provide a natural updraft.

(f) Intake Structure. Intake structures are designed for low intake velocities and with special traveling screens that minimize aquatic life impingement and shock at the intake to the circulating water system.

(g) Discharge Diffusers. Diffusers are mounted at the end of the common discharge pipe in the local surface water to help mitigate the effects of thermal and chemical discharges to the environment by aiding dilution.

4. Possible Needs for Radiation Control Technology in the Future

Some of the radioactive emissions released to the atmosphere, such as krypton-85 carbon-14 and tritium have long half-lives. They might be emitted in large enough quantities to be of concern as nuclear power expands and as these isotopes accumulate in the biosphere.

Krypton-85 is a chemically inert gas with a half-life of 10.7 years. Present reactors emit from a few to 100,000 curies of krypton 85 per reactor-year, depending on design. The krypton-85 released at a reactor represents a small fraction of the total generated, because most of it is retained in the fuel. Furthermore, the radiation doses resulting from the release of krypton-85 from reactors are minute. Released krypton-85 which diffuses through the atmosphere worldwide appears to have very limited health effects: its global health risk has been estimated to be on the order of 7×10^{-5} death per reactor-year. Krypton-85 is therefore not collected for long-term storage at nuclear power plants (ERDA, 1977).

More krypton-85 is released during fuel reprocessing than during power plant operation. However, even if reprocessing were instituted on a large scale, the dose from krypton-85 would remain a small fraction of the natural background radiation dose.

Some carbon-14 is produced in commercial reactors by neutron-induced reactions in the cooling water and oxide fuel. Although quantities are uncertain it appears that 20 to 30 curies/reactor-year are formed. The fraction of this released during reactor operation is also uncertain: the remainder would be released from the fuel only in case of reprocessing.

Release of about one-third of the carbon-14 during reactor operation (as carbon dioxide gas) would result in a population whole-body dose of about 50 manrem per reactor-year, which has been equated to about 0.01 latent cancer fatality per reactor-year. The radioactivity of carbon 14 is potentially of greater concern than this figure indicates, however since it has a half-life of 5,730 years and is incorporated into living matter. The amount of reactor-generated carbon-14 is minute compared with the 200 million Ci of carbon-14 in the atmosphere from cosmic rays and the 6 million Ci from atmospheric weapons tests. Carbon-14 release from reactors could be reduced using existing technology, if the hazard were deemed to justify the effort (ERDA, 1977).

The health interest in tritium, which has a half-life of about 12 years, primarily concerns whole-body dose. Most tritium from the LWR is released as tritiated water and rapidly becomes diluted and dispersed in the circulating waters of the world. The discharge rate of tritium will increase roughly in proportion to the total power generated. Several assessments, however, conclude that the quantities of tritium likely to be released present no significant hazard to the public. It is expected that for at least the next two decades most tritium in the environment will be the result of nuclear weapons testing and that the total inventory will decline during this period.

C. RENEWABLE ENERGY SOURCES

1. Fuelwood

Currently available systems for industrial pollution abatement include control by system design and pollution-collection equipment. Abatement systems for large wood-fired systems consist primarily of air pollution controls. Current methods for controlling water and solid-waste pollution are generally considered adequate to meet environmental requirements. Information on the costs of environmental controls for wood combustion is not available (Dunwoody, 1980).

In industrial wood-fired systems, particulate matter is the air pollutant of primary concern. Sulfur dioxide removal is usually required only for boilers burning large quantities of high-sulfur coal together with the wood. Adequate

control of nitrogen oxide emissions can be achieved through proper boiler design and combustion practices. (Schwelger, 1980).

For good control of particulare emissions, the design of the combustion system and the fuel characteristics should receive careful attention. Among the most important variables are the following:

*Tree species and logging region.

*Type and amount of fuel burned in combination with wood waste (if any).

*Size distribution of fuel particles

*Ash content of fuel

*Firing method

*Fuel distribution in the future

*Air distribution under and over the grate (if installed)

*Grate heat-release rate

*Furnace heat-release rate, residence time, and upward gas velocity

*Furnace configuration

*Design of the fly-carbon reinjection system

*Amount of fly-carbon reinjection

The above factors should be evaluated in the design stage.

Many types of control equipment can be used for removal of particulate matter from flue gases. These include mechanical collectors, wet scrubbers, bag filters, dry scrubbers, and electrostatic precipitators. (See IV.A).

Particulate-collection efficiency of 99 per cent has been demonstrated to meet proposed environmental air quality regulations. The multiple-cyclone system (connected in series) appears to be one of the several promising methods for meeting both mass emission rate and opacity requirements, however, further research is needed in this area.

At present no controls are available for residential units, although research on clean-burning units is underway. The eventual cost of such units will determine the extent of their general use.

Other wood combustion emissions that may be subject to future controls are carbon monoxide, hydrocarbons and nitrogen oxides. In addition if evidence indicates that airborne POM occurring in occupational and residential settings may be responsible for specific adverse biologic effects in man, emission controls could be implemented for both small and large combustion units.

Another aspect of the air pollution problem is the effect of wood combustion on the indoor environment. The discovery that pollutant concentrations are often higher indoors than outdoors signals the need for further research to determine the magnitude of this hazard. The efforts to control indoor air pollution could affect energy conservation efforts as well as safety and building methods (WHO, 1984).

Controls such as careful forest management and monitoring will be required to mitigate the environmental effects of wood harvesting, handling, transportation, and storage.

2. Geothermal Energy

(a) Control of Airborne Hydrogen Sulfide Emissions

The release points for hydrogen sulfide can be divided into two categories upstream of the turbine (pre-plant emissions) and downstream of the turbine (power-plant emissions). The pre-plant emissions include releases from well-field construction and operations such as drilling, well testing, pipeline venting, venting steam through the stack, and well bleeding while on standby. Sources of downstream emissions depend on the conversion process: they include both the steam condensate and noncondensable gas streams.

About 90 per cent of the total hydrogen sulfide releases can be attributed to the power conversion process itself. Depending on the conversion process, most of the emissions occur either from the cooling tower or from the noncondensable gas ejector system. (Stephens et al 1980).

Some of the technologies for control of hydrogen sulfide in the geothermal industry have been adapted from other industrial processes, such as the removal of sulfur from coal gas. Most of these are not suitable for geothermal application because they are slow or costly, or because of the chemical form of the sulfur waste product. The systems that react chemically with hydrogen sulfide such as the Stretford process, seem to be better candidates for geothermal application than systems that depend on physical sorption.

(i) Upstream Abatement Techniques

Upstream abatement has the considerable advantage that if the power plant must be shut down because of unexpected conditions, the stream can be released through the stack because the hydrogen sulfide content will have been reduced. A second advantage of upstream abatement is that less costly direct-contact condensers can be used instead of surface condensers. The use of direct-contact condensers would allow an efficient secondary treatment to be applied to the cooling water and condensate for removal of residual hydrogen sulfide if required. Also, an online secondary treatment system could serve as a backup abatement system when the primary upstream steam is out of service. An additional benefit of upstream removal of hydrogen sulfide

is the reduction of corrosion effects on the turbine and the condenser and cooling water equipment. Unfortunately, there are no demonstrated commercialscale upstream abatement techniques. (US/DOE 1981).

At present one of the best candidates for upstream abatement is the copper sulfate process. It is suitable both for vapor dominated resources and for liquid-dominated resources using flashed steam (Stephens et al 1980).

The stream converter with a Stretfor unit for hydrogen sulfide abatement is another very promising candidate technology for upstream abatement. The process has been well demonstrated in other applications.

For liquid-dominated resources, the binary conversion system together with total spent-fluid injection offers satisfactory hydrogen sulfide abatement.

(ii) Downstream Abatement Techniques

When downstream technologies are used for the abatement of hydrogen sulfide, the major concern is the partitioning of the hydrogen sulfide between the gas phase and the aqueous phase in the turbine condenser. In addition to temperature, the pH of the condensate is a significant factor. The lower the pH, the more the hydrogen sulfide partitions into the gas phase. The pH of the aqueous phase depends on the quantities of hydrogen sulfide, carbon dioxide, ammonia and boric acid present.

The type of condenser is also important, because more hydrogen sulfide is in the gas phase (at the same pH) when surface condensers are used. In a surface condenser, the steam condenses on tubes and is in contact with only a relatively small amount of condensate. In a direct-contact condenser, the steam encounters a spray of cooling tower water whose volume is about 20 times greater than that of the condensate. This large volume of water and the more intimate contact provided by the spray increase the amount of non-condensable gases that dissolve in the aqueous phase and decrease the amount in the gas phase.

In the Stretford process, the off-gas is scrubbed with a solution containing sodium carbonate, sodium metavanadate, and anthraquinone disulfonic acid. This process was originally designed to remove hydrogen sulfide from synthetic fuel gases, and many Stretford units are operating throughout the world for this purpose. The process is very effective: it removes over 99 per cent of the hydrogen sulfide that enters the system. (DOE 1981).

(b) Control of Liquid Effluents

The volumes of waste liquids and gases from geothermal plants are very large. Even if the plant is temporarily shut down, the wells normally are kept operational, so the waste production is continuous.

Only two basic methods of liquid disposal exist direct discharge (surface disposal) or injection. Both methods have been or are being used at geothermal plants around the world.

Treating the spent geothermal fluid before disposal would reduce the problems of injection or permit direct release for either secondary use or surface drainage. Simple treatments would be settling and filtration or flocculation. More advanced treatments, such as reverse osmosis, electrodialysis, or ion exchange, are sometimes used on liquid wastes from industries other than geothermal. The solids that are generated by the treatment process can themselves present a major disposal problem. The primary considerations, however, will be the cost and the effect of depleting the producing reservoir by not returning the liquids.

3. Small Hydro-Power

The presence of dams in flowing waters can block both the upstream and down stream migration of the fish. A fish ladder, which is a series of pools formed by weirs set at intervals across the ladder channel, is typically used to mitigate this problem. The high cost (up to 5 to 10 per cent of total projects costs) of fish ladders has led developers to seek other approaches to the fish-migration problem. The leading alternative is the portage approach, in which migrating fish are attracted to a location, collected, and trucked to a safe upstream (or downstream) location. Other alternatives (similar to fish ladders) are fish lifts and fish locks. Severe fish mortality from passage through turbines and over spillways or from increased predation in reservoirs can be compensated for by supplemental stocking with hatchery-reared fish.

Changes in upstream water levels and downstream flow-release patterns can alter shorelines, affect recreation, and interfere with fish and wildlife habitats. The latter is of particular concern where a hydropower plant is used for meeting peak power demands. Here, the daily fluctuations may play havoc with the ecosystem especially in flatter areas where marshland supports birdlife. The most effective means of mitigating this problem is to design and operate small-scale hydropower systems as run of the river facilities and meet peak power demands by other means.

The development of small-scale hydropower facilities covers a wide range of possible construction activities, entailing varying degrees of potential environmental impacts and needs for mitigating control techniques. In the redevelopment of existing facilities, various states of repair of dam, powerhouse, and turbogenerating equipment will be found, sometimes in combination with an impoundment whose volume has been significantly reduced by sedimentation and may require extensive dredging. Control techniques for mitigating the environmental impacts of dredging operations are in widespread use of channelization, tunnel and pier construction, and other types of water or wetland-related construction.

Changes in the dissolved-oxygen content of the water downstream of the dam can disturb the downstream habitat of a dam site. Here the addition of a hydraulic turbine may decrease the dissolved-oxygen content of the water, especially for periods of low flow during the summer. Mitigation techniques include multilevel outlet structures and oxygen or air injection.

4. Wind Energy Controls

Most of the controls associated with mitigating the environmental problems of wind generators are passive techniques of design and siting, rather than add-on devices.

(a) Safety

Wind-device safety problems related to structural failure should be solvable by structural design analysis and improvement material research and selection, and appropriate site isolation and marking. New composite and fiberglass materials and metals less susceptible to fatigue, are being tested and advanced computer analyses are being made of these complex structures under load and oscillation. These simulations are also seeking to determine fail-safe modes for the control mechanisms.

Electrical safety problems, including interconnection hazards and lightening, can probably be handled by existing safety devices and procedures: however, the interconnection problem will probably require some unexpected investments and may precipitate conflicts over funding.

If the use of medium and large-scale devices becomes widespread aircraft safety can be ensured only by adequate planning, siting, control and marking. Since the rotor tip could extend hundreds of meters above the tower, appropriate lighting and marking of the rotor is essential.

(b) Noise

The only available techniques for mitigating noise are design and lubrication and appropriate siting. Not only the rotor generator, and tower, but the systems design of the entire mechanism and the control devices needs to be examined. It has been suggested that some low-frequency noises are related to the hunting (oscilating without reaching a stable point) of control systems.

(c) Aesthetics

Appropriate siting and pleasing design are probably the only techniques for minimizing aesthetic problems: however, local participation in site choice and public education could be helpful.

(d) Minor Issues

The bird collision problem can be dealt with either by selecting a site outside major known migration paths or by using various combinations of sound and light to divert birds away from sites. However, some birds will continue to collide with wind devices. There is a potential hazard that birds colliding with small-scale devices might contribute to secondary structural failures.

5. Solar Thermal Systems

Solar thermal systems, in general pose fewer environmental hazards during operation than their fossil-fuel alternatives.

For the most part, careful selection of materials for the intended application and operating environment, together with good design practice, will mitigate potential environmental impacts of solar thermal systems. Problems of reflection and glare from collectors are highly site specific and require different solutions for different installations. Often, however, it will be possible to erect barriers between collectors and nearby roads or population centers. In normal operation, tracking and concentrating collectors let less reflected light escape than do non tracking flat-plate collectors: however, misalignment can result in concentrations of sunlight is unexpected areas and perhaps cause harm.

Accidental spills or leaks of solar-equipment working fluids can be minimized through regular system maintenance and the use of chemical management procedures. The latter may include double-wall designs for water or air heat exchangers to separate the heat-transfer fluid from the process fluid. Site development should include containment ponds or dikes to contain spills or leaks. Careful attention to system operations should include the monitoring and maintenance of working fluids.

For disposal procedures, working fluids can be classified as glycols, silicones hydrocarbons and fluorocarbons.

(a) Glycols

The liquid working fluids most commonly used in solar thermal systems are ethylene and propylene glycol-water mixtures. Both are biodegradable, so sewer disposal should be acceptable for limited quantities. (A reasonable procedure is to dilute the mixture with 10 parts water to 1 part clycol-water before discarding it).

(b) Silicones

If silicone fluids are widely used, recycling is an economical means of disposal. If their use is limited, disposal by carefully controlled incinera-

tion is an acceptable alternative, although if requires special equipment to control particulate emissions. Landfill may also be an acceptable solution for disposal of small quantities of waste silicone oils.

(c) Hydrocarbon Oils

Hydrocarbon working fluids are similar to automotive and industrial oils. Methods presently used to dispose of these waste oils include recycling incineration and road surfacing. Economically desirable techniques are burning for fuel and recycling for petrochemicals.

(d) Gases

Waste fluorocarbons have been disposed of by venting to the atmosphere but this is not considered environmentally acceptable. They could be pumped into storage tanks by maintenance personnel and then recycled or properly disposed of by manufacturers.

6. Power Alcohol (Ethanol)

(a) Production

The growing of corn as the primary feedstock for fuel ethanol is not substantially different from the growing of corn for food or livestock feed.

The main environmental impact of crop production is erosion which degrades water quality via sedimentation. This is non-point-source pollution, since there is no specific discharge point at which control technologies can be applied. Discharges to the environment are made over a wide area, and control is very difficult. For this reason, efforts must be directed toward prevention rather than treatment. In the case of agricultural pollution this means minimizing erosion through better farming techniques. Often, however, techniques that serve to decrease erosion increase the need for agricultural chemicals, namely herbicides and pesticides.

Common methods for controlling erosion include contour or strip farming, terracing, narrow crop rows, winter crop cover, reduced tillage and better timing of farming operations. With contour farming, soil loss can be reduced 30 to 50 percent without a loss in productivity. None of the other methods has as great an erosion-reduction potential, so they are less extensively employed. Narrow crop rows provide more ground cover in a shorter time but require increased fertilizer use. Better timing of farm operations means leaving the ground bare for the minimum possible amount of time.

No-till and reduced-till farming are also methods of decreasing erosion. No-till farming is expected to reduce erosion by 50 to 95 per cent although 15 per cent more fertilizer and 11 to 15 per cent more pesticides

are required. Reduced-till methods are similar, but the ground is worked to some extent, which increases erosion and reduced fertilizer and pesticide needs.

Furrow basins, sprinklers, recycling and better scheduling are some of the methods used to decrease water use and the environmental impacts associated with irrigation. The rising cost of energy is encouraging the implementation of better application methods to help conserve irrigation water.

Environmental control measures associated with the harvesting of crop and forest residues are less defined than those associated with agriculture. In general, careful evaluation of existing conditions and long-term effects before harvesting appears to be the best environmental control.

(b) Processing

In general, hardware for control of various pollutants generated in the production of fuel ethanol from biomass is commercially available. The major capital items include systems for flue-gas scrubbing, wastewater treatment and ash collection: vapor-controlled storage tanks; and vent condensers.

Besides control hardware, certain procedures implemented in the workplace constitute effective environmental control systems. Worker health and safety can be protected by minimizing exposure to chemicals by keeping work areas well-ventilated, and by educating workers to follow proper safety precautions in handling toxic or corrosive chemicals and to wear protective gloves and clothing when appropriate. Wherever any volatile organic compounds are in use, precautions must be taken to prevent ignition of leaks or fumes. For example, explosion-proof motors should be routinely used, along with other specially protected electrical equipment.

Because a fossil-fuel-fired steam generator is one of the major sources of environmental impacts at any alcohol producing plant an obvious environmental control measure is the reduction of the amount of process steam required. A second possible control measure is in the introduction of a less polluting fuel source. Two alternatives, oil and natural gas are not economically practical. Future alternatives might be combusion or gasification of agricultural wastes. Three major approaches to reducing the use of process steam are (1) increasing the efficiency of individual steps in the process, or introducing new process steps to replace conventional steps; (2) reusing so-called waste heat whenever possible and (3) siting plants so as to minimize energy consumption.

Opportunities for effective siting abound in the fuel-ethanol industry. Retrofit of food-processing factories or beverage-ethanol distilleries could bring additional fuel-ethanol production on line quickly but perhaps at some cost in energy efficiency associated with the use of older plants. Proximity to abundant renewable or "waste" heat sources can also influence siting

decisions and achieve production economies. Perhaps the most important consideration in site selection is proximity to feedstock sources.

Although environmental controls for fermentation and anaerobic digestion facilities are well established, further research is necessary to develop control technology for gasification plants. Controls used by the petroleum-refining and coal gasification industries are expected to provide a basis for control of emissions from gasification. Identification and characterization of the environmental impacts of all of the technologies is also required in varying degrees (US/DOE 1981).

(c) Conversion

Health, safety and ecosystem concerns resulting from the use of alcohol fuels should be controlled through revised standards or other procedural changes in their distribution, handling and use. Air require technological solutions. Existing oxidation and new three-way catalysts have been shown to be effective in reducing alcohol-fuel exhaust emissions. Furthermore, since neat ethanol and methanol yield no sulfur compounds and no particulates, the catalysts should not be poisoned and should give prolonged satisfactory service. Evaporative emissions may require improved vapor recovery systems. Vapor recovery systems should be effective at reducing evaporative emissions associated with alcohol/gasoline blends, but improved systems designed for increased flow rates may be needed to deal with neat alcohols. In all cases, these controls are expected to involve only marginal costs and should not appreciably increase the fuel costs (US/DOE 1979 (c)).

TABLE 1: ENVIRONMENTAL IMPACTS OF FUEL EXTRACTION FOR ELECTRICITY GENERATION (PER TW(e)h)

Impacts	Coal	Oil	Natural Gas	Nuclear with no-recycle		Fuelwood	Geothermal	Hydropower	Solar Thermal	Biogas
				SM	UM					
Land Use ha	TC Land 230...2700 (SM) 115...330 (UM)	14 for on-shore wells 8 for pipe-line	5.7 for on-shore wells	TC 11.4... 22.8 0.13 PC		Varies with rotation period	Vap D.13.8 Liq.D.3.7	19...475	91	NA
Water hm^3	0.023(SM) 0.042(UM)	1.7 for on-shore production	Nil	NEA		30.8(for plantation and harvesting)	Nil	NA	0.085	NA
Airborne										
SO_x(t)	0.94	1500	12900	3.4	0.07	61		Nil	Nil	NH_3 may be released during collection
NO_x(t)	14	2000	764	2	1	555	Negligible amounts of H_2S, CO, NH_3			
CO (t)	8.5	57	17.5	0.007	0.66	737.5				
HC (t)	1.9	1200	5.43	0.14	0.1	119				
Particulates	0.19	385	17.5	1.7	0.035	36.5				
Others	Coal dust		H_2S			15kt fugitive dust				
Radioactivity $Rn^{220,222}$										
Rn^{222} Ci	Neglible			112	677					

Impacts	Coal		Oil	Natural Gas	Nuclear with no re-cycle	Fuelwood	Geothermal	Hydropower	Solar Thermal	Biogas
Liquid Waste	SM	UM								
TSS(t)	3.8	176	$80hm^3$ brine	Brine NEA	Drainage water with dissolved and suspended Uranium	11 ha^3 acqueous waste	Nil	Nil	Nil	BOD = 9kt
TDS(t)	197	4100								
Sulphate(t)	135	1800								
Ammonia(t)	0.19	3								
Solid Waste										
Tailings	1100 (SM) 14 (UM)		Neglible	Neglible	148 ... 579	Residuals used as fuel	Nil	Silt precipitate behind dam	Nil	Usually no actual waste
Occupational Health Hazards	SM	UM								
Labour m/y	64	194	33.8	48	10.9 38.2	1800	NA	NA	NA	NEA
Total Fatalities 10^{3} [1/]	14	217	63	11...18	5.7 19.4	200				
Injuries/ Disease	2.1	19.4	5.44	1.8...1.9	(0.34..(0.57.. 0.8) 1.14)					
WDL	82.3	698	113	42.5	10.6 16.3	1400				

Abbreviations: SM – Surface Mining; UM – Underground Mining; NA – Not Applicable; NEA – No Estimates available
WDL – Work Days Lost; TC – Temporarily Committed; PC – Permanently Committed

1/ Figures given are multiplied by 10^3, to get final values divide by 10^3 (e.g. 14 x 10^{-3} for surface mined coal)

Impacts	Coal	Oil	Natural Gas	Nuclear with no recycle	Fuelwood	Geothermal Energy	Hydro-Power	Wind Energy	Solar Thermal	Biogas
Occupational Health Hazards										
Labour m/y	12	28	3.6	19.5 ... 26.6						
Fatalities[3/] x 10^3	570 .. 1000	0.63	0.046 ... 0.34		Refer to Table 1 on Fuel	NA (see conversion Table 3)	NA	NA	NA	See conversion Table
Injuries/ Diseases	0.16	0.83	0.006 ... 0.04	14.8						
WDL	21.3	184	0.1 ... 0.28	55						

Abbreviations: TC - Temporarily Committed; PC - Permanently Committed; DU - Direct Use; EZ - Exclusion Zone; TSS - Total Suspended Solids; TDS - Total Dissolved Solids; BOD - Biological Oxygen Demand; NA - Not Applicable; NEA - No Estimates Available; WDL - Working Days Lost

TABLE 2: ENVIRONMENTAL IMPACTS OF FUEL PROCESSING FOR ELECTRICITY GENERATION (Normalised to 1 Tw(e)h)

Impact	Coal	Oil	Natural Gas	Nuclear with no recycle	Fuelwood	Geothermal Energy	Hydropower	Wind Energy	Solar Thermal	Biogas
Land Use (ha)	9...23(TC) 0.8 (FC)	0.24(DE) 0.24(EZ)	1.37 ... 2(TC)	TC=0.725 FC=0.2	Refer to Table 1 on Fuel Extraction	Refer to Table 1 on Fuel Extraction	Refer to Table 1 on Fuel Extraction	NA	NA	1.1
Water hm^3	2.3 ...57	3 ... 57	3 for cooling and 0.57 for MU	0.9393 ... 0.9713		NA		NA	NA	Recoverable
Airborne										
NO_X(t)	0.016	2600	110	1495	Refer to Table 1 on Fuel	NA (see conversion table 3)	NA	NA	NA	Negligible amount of leaked H_2S from digester Odour could be a nuisance
SO_X(t)	2.4	2200	30	396						
CO(t)	0.8	530	2.4	10.1						
HC (t)	0.8	Organics 3850	2.4	4.4						
Particulates(t)	3.2	338	2.4	390						
Fugitive Dust(t)										
$H_2O(hm)^3$										
Rn^{222}(Ci				0.88						
Ra^{226}(mCi)				1.4						
Th^{230}(mCi)				1.6						
U(mCi)				7.11						
Others		Ammonia 279(t)	Aldehydes 0.3 (t) + Organic (t)	Fluoride 0.72 (t)						

Impacts	Coal	Oil	Natural Gas	Nuclear with no recycle	Fuelwood	Geothermal Energy	Hydro-Power	Wind Energy	Solar Thermal	Biogas
Liquid Waste TSS (t)	2.4	0.12 hm^3 containing oil, grease, phenol, ammonia suspended and dissolved solids and metals	condensate stripper bottoms of which consists mainly of chloride and sulphate	effluent containing toxic substances	Refer to Table 1 on Fuel Extraction	NA (see conversion table 3)	NA	NA	NA	Digester effluent is used as fertilizer or water is recovered and solids are added to sludge
TDS (t)	132									
Sulphate(t)	72									
Ammonia(t)	0.16									
Radio-activity U(mCi)				18.2						
Ra^{226}, Th^{230} (mCi)				0.92						
Rn^{222}(mCi)				28.4						
Solid Waste	About 47 ht of coarse and fine refuse	NEA but no serious environmental impacts are expected	NEA but no serious environmental impacts are expected	Mill tailings 37kt U and daughters 98Ci, Ra^{226}(25 Ci) Th(23 Ci)	Refer to Table 1 on Fuel Extraction	NA	NA	NA	NA	Sludge used as fertilizer

TABLE 3: ENVIRONMENTAL IMPACTS OF FUEL TRANSPORTATION FOR ELECTRICITY GENERATION

Impact	Coal	Nuclear with no recycle	Natural Gas	Oil	Fuelwood	Geothermal Energy	Wind Energy	Solar Energy
Air Pollution	Fugitive coal dust	Radioactivity	H_2S	H_2S	Dust	NA	NA	NA
Water Pollution	Water used in slurry pipelines should be treated before discharge	Radioactivity in case of accident	Spills of LNG in case of accident	Oil spills from routine and accident situation	Nil	NA	NA	NA
Impact on Land	Contamination in case of accident Land area required for pipelines	Radioactive contamination in case of accident	Land area required for pipelines	Oil spills in case of pipeline accidents Impacts of oil spills on coastal areas	Nil	NA	NA	NA
Occupational Health Hazards								
Accidental fatalities x 10^3 2/	1.6 ... 140	1.1	1	5.7 ... 8	48 1/	NA	NA	NA
Radiation induced fatal cancers x 10^3	Nil	0.05		Nil	Nil			
Accidental injuries/disease	0.03 ... 2.3	0.00114	0.14	0.034 ... 0.66	23.3 1/	NA	NA	NA
WDL	36	NEA	2	11.2	NEA	NA	NA	NA

Impact	Coal	Nuclear with no re-cycle	Natural Gas	Oil	Fuelwood	Geothermal Energy	Wind Energy	Solar Energy
Radiation induced non fatal cancers 140 2/	Nil	0.063	Nil	Nil	Nil			
Public Health Hazards								
Fatal cancers 110 3 2/		0.05						
Non fatal cancers 110 3 2/		0.053						

1/ Morris (1981).

2/ Accident fatalities are multiplied by 10^3 or 10^5. Divide by 10^3 to get final figures (e.g. 1.6 ... 140 x 10^{-3}).

Abbreviations: NA - Not Applicable; NEA - No Estimates Available; WDL - Working Days Lost.

TABLE 4: ENVIRONMENTAL IMPACTS OF FUEL CONVERSION INTO ELECTRICITY AT THE POWER PLANT
(Normalized to ITW (e) h)

Impacts	Coal	Oil	Natural Gas	Nuclear with no recycle	Fuelwood	Geothermal Energy	Hydro-Power	Wind Energy	Solar Thermal	Biogas
Land (n)	1.9 ... 2.5	0.4 ... 0.72	0.2...0.42	0.23 ... 0.29 113 (EZ) 7000 (LTZ)	2.97	3.4	Included in reservoir area	Given in connection with extraction	Given in connection with extraction	0.2 ... 0.42
Water hm^3	120 for cooling 0.258 for MU	120 for cooling 0.258 for MU	120 for cooling 0.258 for MU	222 for cooling 0.44 for Mu	120 for cooling 0.258 for MU	3.6 for MU for cooling tower if used		Nil	0.085 for process and maintenance	120 for cooling 0.258 for MU
Airborne						VDS LDS				
SO_x (t)	12800	4200	2.3...2.5		390	H_2S(t) 26.5 12 ... 120	H_2O	Nil	Nil	1170 ... 2320
NO (t)	3000	2850			1170 ... 5800	NH_3(kt 0.25...5.6 0.46 ... 47				1140
CO (t)	230	81	70		235	CO_2(kt) 26 18.7 ... 187				
HC (t)	46	54	4		765	H_3(t) 0.13 6.24				
Particulates(t)	900	137	58...132		2600 ... 3500	Boron(t) 0.259 31 ... 313				CO_2(kt) 35(t) H_2S(kt)
Others	1.1Mt CO_2	Aldehydes 27t		PWR BWR	Aldehydes(190-630)t	Particulates(t) 21 33 ... 49 Ci	NEA 127(1028) Ci			568 .. 1136
Radio-Activity	11.4 mCi(Ra)	0.12 mCi (Ra,Rn, Th		X_e(Ci) 1500 Kr(Ci) 93 H^3(Ci) 24 C^{14}(Ci) 0.7 I(mCi) 16.5	10500 6060 10 1.6 1480	Rn^{222} 127 Ci	33 ... 49 Ci			

Impact	Coal	Oil	Natural Gas	Nuclear with no recycle	Fuelwood	Geothermal Energy	Hydro-Power	Wind Energy	Solar Energy	Biogas
Liquid Waste										
TSS(t)	57	57	57	Depends on flow		If not reinjected into geothermal reservoir brine will represent a serious problem	NA	Nil	Boiler blow down may contain hydrocarbon oils, corrosion inhibitors, pH controls etc.	9750
TDS(t)	457	1196	200							
BOD(t)	0.27	0.3 ... 16	0.3... 1.2	0.31						9000
Organics(t)	8.5	7.5	7.5	8.93	5000					
Chromates(kg)	0.2	228	228	310						
H_2SO_4(t)	9.4	9.4	9.4	11.1						
Cl_2 (t)	3	3	3	3.2						
Boron(t)	38	38	38	45						
Phosphate(t)	4.8	4.6	4.8	5.1						
Waste Heat TWh	1.27	1.27	1.27	2	2.4		NA	Nil	1.5 ... 12.15	About 1.27
Radioactivity				2046 Ci						
Solid Waste										
Main contents	Ash	Flyash	Nil	Spent fuel 4.04(t)U, 0.04(t)Pu	55t of TOM in 6kt of ash	600m^3 of sludge	NA	Nil	Nil	Filer cake contains varying amounts of metal trace (Zi, Cu)
Amount(t)	41000	1050								
Radioactivity (Ci)	Ra^{226} Ra^{228} 0.1	(Ra,Th 0.0003		Estimated Radioactivity 1.6 MCi from spent fuel and 580 Ci from waste		Nil	NA	Nil	Nil	

Impacts	Coal	Oil	Natural Gas	Nuclear with no recycle		Fuelwood	Geothermal Energy	Hydro-Power	Wind Energy	Solar Energy	Biogas
Occupational Health Hazards				NF[1/]	WM[1/]						
Labour m/y	37	31.7	37	133		82.5	16.95	17.1	120	239	170.8
Fatalities x 10^{3}[2/]	3.4 ... 50	1.50 ... 2.30	1 ... 2	16.50	0.053	40	38	0.65... 3.3	10.06	74	42
Injuries/ disease incidents x 10^{3}[2/]	460 ... 680	170 ... 1630	130 ... 1830	168	0.06		200				
WDL	17 ... 25	2.8 ... 31	2.2 ...31	2.8	2.5	22.1	4.51	0.02	137	269	152

1. Abbreviations used: CT - Cooling Tower; EZ - Exclusion Zone; LFZ - Low Population Zone; MU - Make-up; POM - Polycyclic Organic Matters; HLW - High Level Waste; NF - Nuclear Power Plant; WM - Waste Management Plant; RP - Reprocessing Plant; VDS - Vapour Dominated Systems; LDS - Liquid Dominated System; PWR - Presurized Water Reactor; BWR - Boiling Water Reactor.

2. Figures given in table are multiplied by 10^{3}. To get final values divide by 10^{3} (e.g. 3.4 ... 50 x 10^{-3})

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TECHNOLOGICAL DEVELOPMENT AND ENERGY PLANNING IN AFRICA

NOVEMBER 1984

Introduction:

1. Technological development as a powerful tool for socio-economic development, is highly dependent on energy. Hence energy planning is a prerequisite to a national utilisation of available energetic resources, thus leading to a successful technological development, and a realistic socio-economic development. For many African countries, the process of socio-economic development was nearly stifled by the events of the 1973 oil price rises. Apart from the particularly adverse effects of these events on the economies of most developing countries, the problems also awakened the indigenous experts to the need to explore new and renewable sources of energy (NRSE) in order to meet local demands and thus become less dependent on imported fuel.

2. In recognition of this need to develop and promote the use of new and renewable sources of energy, the United Nations Conference on New and Renewable Sources of Energy, which met in Nairobi from 10 to 21 August 1981 has accorded a high priority to this energy sector in its Programme of Action, called the Nairobi Programme of Action for the Development and Utilization of New and Renewable Sources of Energy (NRSE). Energy Planning must necessarily be in line with this Nairobi Programme of Action. In this planning process one must establish priorities in the field of NRSE. It is necessary to consider a large number of parameters such as the availability of resources, the state of development of technology involved, the size, type, geographical location and time-frame of the energy requirements, the characteristics of the end users, as well as social, economic, environmental and technical considerations, the potential of increased energy efficiency and conservation and the relative impact on the energy transition. In this context, priority actions should be assigned to certain urgent programmes concerning principal energy needs in rural/urban areas of African countries and to a number of technologies utilizing NRSE which have reached a stage of maturity at which little or no further research and development are required for their widespread utilization.

3. The energy planning must therefore also [illegible] channels and procedures for the widespread diffusion or transfer of technology to all African countries, under conditions of mutual benefit to all parties, taking into account the basic needs for survival of rural/urban population of Africa. Such channels need to be established and supported through TCDC programmes or international co-operation, particularly in those cases where such technology originates in the developed countries.

4. Crisis situation in Africa

The present crisis situation in Africa where over half the population is affected by drought and food shortages, and where famine is affecting over six million people right now, calls for an urgent action from all concerned. Those technologies, readily available, utilising such energy sources as are easily exploitable, have to be adopted without further delay. It is time the nations and the experts stop speaking and start acting ! Simple solar technologies that can be easily applied are still in the drawers of many experts and government officials. Appropriate technologies, whatever their origin, have to be adapted and exploited in the African regions that are threatened by the crisis. Short term measures have to be singled out from long term measures, in order to cope with the situation. Technologies for survival must be a priority, and the pace of development and application of these technologies will determine the fate of African countries.

5. Solar energy as the principal energy for basic and urgent needs

Africa generally has not only a very low rate of energy consumption per capita, but it also exhibits within its boundaries a strikingly inequitable distribution of energy between rural and urban populations. Among the several potential new sources of energy, solar energy holds promise as a major supplementary source. Worldwide attention is now focused on methods of exploiting solar energy for a vast range of applications.

6. Discussion of potential application of solar energy and its possible benefits (by way of increasing energy supply in rural areas and in reducing human drudgery) will require consideration of sunlight's direct and indirect forms and its associated technologies. One should recognize that traditional sources of energy in most African countries, especially in rural areas, are already based heavily on the indirect conversion of solar energy; this occurs through photosynthesis in the form of final wood and agricultural residues, which constitute a major portion of the total energy consumption. Indeed, biological applications of solar energy are gaining increasing

importance. Efforts aimed at attaining a sustainable rate of consumption of these sources, through planned use of forests and development of fast-growing species of plants, are considered essential.

7. The use of solar energy in Africa must be viewed in different countries within the national context; they must take into account local rural situations. The foremost requirement is an inventory of energy basic needs, identifiying the relative quantity of energy required for various activities and, in addition, the pattern of energy consumption relating this quantity to the nature of its end-use. Thus it is considered extremely important that new energy technologies should be able not only to provide the required amount of energy but that this should be matched to the quality of its end-use.

8. It is useful to know the various energy needs that could be met by using solar energy, keeping in mind the element of appropriateness to the situations in African countries. The energy is required for domestic use (lighting, cooking, hot water, heating), agricultural processes (grinding, drying, storage, refrigeration), agriculture (irrigation, plenting, cultivation, harvesting), water pumping (drinking and household consumption, cattle watering, irrigation), social and community needs (health services, drinking water treatment, education). While it is difficult to envisage that any of the new and renewable sources of energy would be able to offer short-term solutions on a significant scale, they do offer the prospect of indigenous, readily available, and inexhaustible supplies which -through sustained efforts - can bring about an improvement in the quality of life of the people. A further advantage of renewable energy sources is their compatibility with the environment.

9. Examples of appropriate technologies utilizing NRSE available in Africa:

- Technologies for food production, processing, preservation, transport and marketing.

  Amongst the various technologies available, it is worth while mentioning the following, using mostly solar energy or its derivatives: solar driers, solar engines and pumps, solar refrigeration for cooling and storing agricultural products, solar stills for distillation, wind mills for local power generation, and the low-cost multi-purpose plowcart called 'krishimitra', developed in India. This last one can

be used for such farm operations like tilling, ploughing, cultivating, ridging, planting, harrowing, thrashing, irrigating, water pumping, grass-cutting and transporting farm inputs and products. It uses a six horse-power diesel engine, and has a load carrying capacity of one thousand kilograms.

- Technologies for domestic purposes. These include solar cookers, water pumps, water heaters, water purifiers, biogas generators and domestic stoves. The solar cookers and domestic stoves have the major advantage of reducing wood fuel consumption, thereby reducing deforestation and desertification. Small household biomas generators are also becoming very popular where sufficient biomas and water are available. The efflux from these biogas generators offer very valuable fertiliser material for the gardens.

- Technologies for social and community purposes, rural industries. These include pottery, spinning and weaving, furniture, metal work, community biogas digestors, biomass plantations, small hydropower, photovoltaic pumps and photovoltaic communication centres, etc.

10. It must be emphasided that all these technologies mentioned in the three sectors above are appropriate to African context, utilise little energy, mostly from new and renewable sources, and are easily available. In the process of energy planning, these are the technologies that have to be given priority, as they are suitable not only for improving the quality of life of the people, but also for giving them a technological base necessary for further technological development.

11. Need for 3 scenarios in energy planning

The scenario No.1 consists in the immediate application of measures to exploit available technologies with:

- identification of technologies that are sufficiently developed to the stage where their active promotion and use can be encouraged through dissemination of information and the establishment of demonstration, and replication units.
- identification, assessment and selection of technologies with the potential of being up-graded and commercialized on a large scale;

- Identification of institutions capable of undertaking the development work on the selected techologies and assignment of the up-grading work to these institutions;

- Conduction of training sources in selected institutions and demonstration sites.

12. The scenario No.2 consists in giving priority to the NRSE. African involvements in the area of development and promotion of NRSE are mostly just beginning. It is thus necessary to study, from an African point of view and outlook, the experiences of industrialized countries and, especially, those of Third World Asian countries, in order to propose the course of action necessary for the development and promotion of NRSE in Africa. It will be greatly rewarding if this work succeeds in making a modest contribution to the solution of the grave energy crisis presently plaguing African countries.

13. The scenario No.3 consists in taking measures with medium and long-term perspectives, like:

- promoting endogenous innovative activity and establishment of linkages between innovative systems and productive systems within the region, with increased research and developmental capabilities;

- promoting technical cooperation among member States in the fields of NRSE technological information and industrial property;

- providing assistance to the existing industrial property offices of member States with respect to:

  a) functions of an industrial property system hitherto omitted in the region:
     - promotion and encouragement of local research and national innovative activity in NRSE;
     - provision of advice and finance to needy indegenous investors in NRSE;
     - provision of information at national, regional and international levels on NRSE.

b) Establishment of or strengthening linkages with relevant development sectors and other potential users of NRSE:

- assisting member States in the development of low-cost technologies for any kind of energy sources.

14. Fiscal and promotional incentives

In order to popularise new and renewable energy systems, and stimulate technological development and economic growth based on these systems, it is necessary to provide financial and other promotional incentives to manufacturers and users of new and renewable energy equipments and gadgets. In many cases the initial costs of renewable energy equipments are high in relation to products utilising conventional energy sources, because of inadequate technological development, high cost of materials (solar photovoltaic as an example) and low scale of production. Measures that can be adopted are:

(a) Accelerated depreciation on machinery or plant used for manufacturing new and renewable energy systems and devices;

(b) exemption from central excise duties on such equipments;

(c) Bank loans on concessional terms to manufacturers and users of such equipments;

(d) free provision of patents and licenses to manufacturers, where possible.

These measures will surely accelerate the production and utilisation of such equipments.

Conclusion

The present pattern of economic and technological dependence is not congenial to the development of African countries. Continuing adjustments and institutional and structural changes in the international economic relations are required, in line with the objectives of the New International Economic Order. While this takes place, African countries must turn to themselves and, with strong political will and social committment, harness all their energies in their technological transformation. Effective energy policies, effective energy planning, and the application of available appropriate technologies are the very first steps towards this technological transformation and ensuing independence vis a vis the developed economies. Self reliance, self-sustained development with maximum exploitation of indigenous resources are goals that tally with the paths set out in the Lagos Plan of Action for the socio-economic development of Africa.

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THE ENERGY SECTOR IN THE NATIONAL ECONOMY:

PLANNING AND STRATEGIES IN SOME AFRICAN DEVELOPING COUNTRIES

NOVEMBER 1984

1. Introduction

The sharp increase in the price of energy during oil crisis of 1973 and the associated changes in the relative costs of alternative energy sources have imposed a colossal planning and strategy burden on developing african countries. In all member States there was a need to conserve energy and to replace expensive sources of energy with cheaper ones. Those african developing countries that rely heavily on imported oil, especially, need to step up their efforts to identify and invest in their own energy resources. Designing and carring out strategies for the energy transition in Africa requires better planning both within enterprises supplying energy and at the national level, where there is a need to coordinate the activities of suppliers and to promote efficiency in energy consumption. The quality of planning is the key to future investments; not only to identifying projects and implementing them successfully, but also to raising the finance for them.

The deterioration in economic conditions in african developing countries, the condition that has been prevailing for the last decade, continued during1984. Faced with a critical economic environment, african governments have intensified their search for adjustment policies, including those relating to energy sector.

2. The current energy situation in Eastern and Western Africa

In the World Bank Annual Report for 1983 there is an analysis of energy situation in member States of Eastern and Western Africa and regional perspectives for these areas are outlined.

(a) Eastern Africa

In Eastern Africa the Bank, together with UNDP has completed energy assessment reports for Burundi, Kenya, Malawi, Mauritius, Rwanda, Zambia and Zimbabwe : others are under way (as in Sudan and Uganda), or will soon be scheduled, in the rest of the region's member countries These reports have provided a good basis for discussion and meaningful policy action.

The emphasis of energy policy must be on expanding local production, since the scope for conservation is limited by low levels of present, per capita consumption. The region has large hydro, coal, and geothermal potential that awaits exploitation. Potential also exists in the long run for utilizing, economically, energy from the sun and wind. There is room for considerable improvement in the utilization of energy from fuelwood. The charging of economic prices and suitable taxation of petroleum products must sharpen incentives for saving foreign exchange and exploiting local resources.

The hydroelectric potential in the region is very large, particularly in Ethiopia, Uganda, Zaire, Zambia and Zimbabwe. Only a small part of this resource has been developed so far. The cost of installing generating capacity can vary from $1,000 per kW (1980 prices) for small units to $2,600 per kW for large ones. The Bank has played a substantial role in helping these countries do design least-cost solutions to their power needs, to establish and develop institutions in this sector, and to mobilize external finance for hydropower investments. In addition, financing has been provided for coal-based power projects in Botswana and Zimbabwe. These conventional projects constituted nearly 82 percent of total energy lending by the Bank to Eastern Africa in fiscal 1983.

While hydro and coal-based power is important, by far the most important source of energy in the region is fuelwood. It accounts for over 90 percent of total energy production and consumption, except in a few countries of the region. Mounting demographic pressure and the wide-spread practice of consuming wood as a free good without replanting it have precipitated a supply crisis in some areas. If current trends continue, however, environmental damage will accumulate and cause serious injury.

To some extent, demand for fuelwood can be restrained by improving the efficiency of its use. In Burundi, Kenya, Malawi, and Rwanda, the Bank is participating in attempts to improve the efficiency of wood and charcoal burners and to introduce cooking stoves. Conservation in industrial processes is improving; for example, in Malawi, attempts are being made to improve furnaces and burners designs in the tobacco industry with a view to reducing consumption of fuelwood by 50 percent.

Another recent thrust of Bank lending in Eastern Africa is for exploration and development of indigenous energy sources. In fiscal 1983 finance was extended for coal engineering in Zambia and Tanzania, as well as petroleum exploration in Ethiopia and Madagascar. Activities financed by the Bank in gas exploration in the Songo Songo field area in Tanzania have resulted in gas finds to date that have far exceeded earlier expectations (about 500 billion cubic feet). Proven reserves are now established, which are the equivalent of sixty-five years to seventy-five years of electricity consumption at existing levels. In Kenya, two Bank-assisted geothermal projects totaling 30 mW, supplied 10 percent if the country's electricity consumption in fiscal 1983.

Eastern Africa's potential in other renewable resources, biomass, solar, wind, small hydro - holds out promise in the long term that the needs for small-scale decentralized power sources for agricultural and rural development can be met. The Bank is encouraging solar research in Zimbabwe and Mauritius; and in Burundi, the use of peat.

Possibilities for conservation of imported energy, and therefore for saving foreign exchange, are also being explored within the transport sector, which on the average, absorbs about half the oil imports in Eastern African countries. This burden of imports is particularly acute for the land locked countries, which had to pay landed costs averaging $100 per barrel of oil in 1982. Overall, most countries seem to be moving toward a more efficient use of energy by improving maintenance procedures for roads and vehicles and by acquiring light, energy efficient vehicles. Possibilities for saving fuel are also being tapped in the industrial sector; for example, the substitution of coal for petroleum in the Bamburi cement factory in Kenya will reduce fuel costs by at least 25 percent. In Zaire, the change-over from using oil-fired boilers for heating and producing process steam to electric boilers means that idle hydropower capacity there will be put to use.

In general, Eastern African countries have reacted to the increase in petroleum prices during the period 1974-81 by passing them on the consumer. However, distorting exist, and a common one has been subsidized diesel fuel and kerosene. To determine the cost of supply and to design a structure for tariff rates, the Bank has financed many tariff studies. Based partly on these analyses, power tariffs in 1982 rose by 50 percent in Tanzania, 20 percent in Swaziland and 8.5 percent in Malawi. An increase of about 85 percent took place in Sudan, in mid-1983.

(b) Western Africa

The problem of energy supply in Western Africa is primarily that of fuelwood, which in most countries, accounts for more than 80 percent of all energy consumption. The depletion of forest capital is most pronounced in the Sahelian countries, but even in the coastal States further South, local imbalances between supply and demand create similar problems on an increasing scale.

Current wood consumption in the Sahelian countries is approximately one kilogram of dry wood per person daily and far exceeds the capacity of local forest resources. If wood-consumption practices continue unchanged, only 65 percent of domestic energy needs will come from natural forests and managed tree plantations by the year 2000. Most countries will have to halve their fuelwood consumption by the turn of the century if there are to be any forests left. Reduction in wood consumption can be achieved through more efficient usage and substitution of other energy sources, but considerable deforestation also takes place because of land being brought into cultivation and because of overgrazing. A recent study by the FAO estimates that the areas affected add up to a million hectares each year in the Sahelian countries. Consequently, in order to avoid irreversible damage to the environment, agropastoral programmes are needed in addition to those designed to deal with the fuel-wood scarcity.

It is becoming apparent that afforestation is only a partial solution to the fuelwood supply problem. A more comprehensive approach to energy supply in rural regions is necessary, specifically to examine how commercial energy could become a substitute for fuelwood (by appropriate policies on pricing, supply, changing traditions, and introduction of efficient appliances).

Commercialized energy supply to the modern sectors of the National economies in Western Africa is hampered by the lack of basic infrastructure. Hence, much Bank activity is being directed toward improved knowledge of energy resources. Petroleum-sector assistance is being provided to nine countries to promote exploration and eventually, exploitation of indigenous resources. Inventories of hydroelectric-power resources are being made under IDA technical-assistance credits to Benin and Togo and under an IBRD-administered UNDP grant to Guinea. Because the major hydro resources of the region are concentrated in a few countries, the preparation for their development will be facilitated by regional co-operation in joint studies of water resources and electrical interconnections. The Bank supports therefore, the organizations established for such a purpose by the countries of the region, such as the Niger Basin Authority.

Another problem in meeting the energy requirements of the modern sector in Western Africa is that of institutional weakness, the root cause of which is a shortage of trained manpower. In Bank technical-assistance projects, increasing attention is being paid to manpower-training needs in those energy-sector entities that have difficulty coping with the demands imposed by economic growth. In addition, there is increasing concentration on the relationships between the governments and parastatal enterprises, as well as to their rehabilitation.

In developing African countries energy planning and policies must take into account the socio-economic duality created by co-existence of a modern and a traditional sector.

This duality is characterized by different patterns of energy consumption and supply: in the modern sector, life style and technologies resulting in energy use mostly based on petroleum; in a traditional sector, a subsistence economy, based on low-energy intensity, dispersed demand and supply, but are often threateningly high consumption of limited fuelwood resources. Many african developing countries are affected severely by both oil and fuelwood crises, which reinforce one another.

National energy planning cannot be undertaken in a vacuum. While all countries should strive for reasonable self-reliance, the nature of interdependent world demands co-operation and co-ordination with neighbors in the region.

National energy planning can be described as a process whereby a country (1) determines its needs; (2) carries out an appraisal of available resources; (3) determines the best means to develop the energy resources (or alternatively to import them), and (4) organizes the necessary skiles and financing from internal sources (including the private sector) and from international sources as needed.

4. Formulation and coordination of national strategies

Once a diagnosis of the country's energy issues and options has been carried out (either internally or with external assistance such as through an Energy assessment Report), the three tasks facing the Energy Ministry are:

(i) Identify and obtain government consensus on the priority policy or investment areas for follow-up;

(ii) identify and get agreement on the agencies that will carry out the required follow-up work in specific priority areas; provide them with guidance or technical support needed for this.

(iii) solicit external financial or technical assistance required for these priority projects and seek to ensure that donor assistance is channeled first to the agreed priority areas.

There are a number of ways of organizing this process and appropriate institutional arrangements will vary from country to country but in almost all cases they will require the presence of a small group of technical/economic staff whose main task will be to orchestrate the process and serve as a focal point for coordinating the work of subsector and donor agencies. Regardless of where it is located, this group will need to have access to senior policy makers. To accomplish the first two tasks it may also be useful to establish an interagency co-ordination committee, for which the small energy planning group could act as a technical secretariat.

In the third area - obtaining donor assistance for priority projects - a major constraint is the shortage of well defined and justified project profiles which would translate initial project ideas into a specific program of work required to prepare and implement the project. This will help to overcome the current paradoxical situation of a surfeit of potentially profitable projects that are not being developed in many countries and, at the same time, the difficulty that many donor agencies are having in identifying priority projects to assist in the energy sector.

5. Conclusion

One of the most difficult tasks facing the majority of the African developing countries (but one that is unavoidable if they are to resume healthy growth) is to adjust their economies to the higher costs of energy. For many, expanded investments to increase energy production and to raise the efficiency of their energy use will be central to the process of economic growth. These investments require:

(i) The mobilization of funds on an unprecedented scale, both externally and from domestic sources, particularly through operating surpluses in energy enterprises; and

(ii) the upgrading of human resources to ensure that investments in energy development form part of a rational strategy, and that energy programs and projects are designed and executed in a cost-effective manner.

The principal objective of the Bank's energy program is to assist developing countries to define and implement an appropriate development strategy for energy sector. The urgency and the magnitude of the necessary structural adjustments demand greater attention to policy and management issues, preinvestment studies to formulate better strategies for energy supply and utilization, and the mobilization of financing. The Bank functions as a catalyst in promoting strategy formulation, policy reform, and institutional improvements; and in mobilizing external sources of technology and finance to implement effectively the changed investment priorities in developing countries. It has expanded and diversified its energy lending and is putting greater emphasis on assisting borrowers in the choice and use of new technologies, strengthening institutions, and improving the policy framework in the energy sector.

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Washington, D.C. March 5-9, 1984.

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"USE OF NEW AND RENEWABLE ENERGY SOURCES IN BUILDINGS"

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Use of New and Renewable Energy Sources in Buildings

1. Shortage of energy and economic underdevelopment go hand in hand, a fact which has confronted the developing countries in an increasingly serious manner since the first oil crisis in 1973. Very few of those developing countries which have no oil reserves have shown any sign of a significant recovery in their economic growth rates during the past decade. To increase the availability of energy at affordable costs becomes, therefore, one of the prime goals of economic planning in all developing countries. Since energy consumption is quite significant in the organized (largely urban and industrial) sectors of developing countries, attention has to be focused on measures which can stretch existing sources of supply as well as on those which may enable locally available sources of energy to be effectively utilized. One such source is solar energy which is abundantly available in most of the developing countries, whose large-scale application has hitherto been hindered by economic, technological and institutional constraints.

2. The United Nations Conference on New and Renewable Sources of Energy, held in Nairobi in 1981, proposed, inter alia, measures to promote the development and utilization of new and renewable sources of energy in order to meet overall energy requirements, especially those of the developing countries. The work programme of the United Nations Centre for Human Settlements (Habitat) for 1984-85 includes a review and analysis of data on shelter development projects organized around renewable energy requirements. Activities related to this objective include preparation of guidelines for the production of national handbooks for application of passive solar heating and natural cooling design principles in developing countries. Evaluation of a number of case studies on settlements or buildings using passive design heating and cooling principles will also be undertaken.

3. The consumption of energy in buildings extends over three phases. First, the primary energy used in the production of modern building materials such as cement, steel and bricks, accounts for up to 25 per cent of the total commercial energy consumed in developing countries. Secondly, the process of construction itself requires commercial energy in the form of transportation of materials and use of equipment. Thirdly, extensive use is made of energy in the form of light, heat and working modern appliances, during the life of the building to meet the requirements of comfortable usage.

4. The building industry does not seem to have paid much attention to the adoption of materials and technologies for construction which result in conservation of energy. It is, therefore, essential to consider ways and means to utilize indigenous, local, low-energy materials, such as lime, pozzolana cement, adobe and stone. This would not only conserve energy at the building material production stage but considerably reduce energy costs during the construction phase by minimizing transportation.

5. It is known that in many developing countries a great percentage - approximately 35 per cent of total energy demand - is used in lighting, heating and cooling buildings. It is, therefore, extremely important that bioclimatic design considerations be the starting point for any building project. The present practice of designing a building from structural and cost considerations alone and then handing it over to the "climate people", namely, the lighting, heating and air-conditioning engineers, to create comfort conditions within the building often leads to the situation that electrical and mechanical systems have to compensate for design shortcomings, such as unsuitable orientation, neglected daylighting and inadequately analysed solar gains and losses, leading to much higher energy requirements than would be the case following an integrated bioclimatic design approach.

Passive Solar Heating

6. Passive solar heating designs can be most effective in temperate climates where there is sufficient sun to make them work well and winter temperatures are cold enough to make them cost-effective. In regions of mild winter climate - those with average monthly midwinter temperatures in excess of about 8°C - buildings normally have low thermal resistance and are uncomfortably cold throughout much of the winter. In these climates, passive solar heating alone, without added insulation, can markedly improve inside winter climate. In regions of severe winter climate - those with average temperatures below about 8°C - insulation must be added to achieve reasonable comfort levels.

Design Consideration

7. Passive solar technology is basically design-oriented. Much the same building materials are used as in conventional construction, but the building is put together differently to take maximum advantage of environmental conditions to enhance thermal comfort. The choice of passive solar design strategy should be based on a balance of:

(a) Life style use patterns of the building;

(b) Construction techniques and materials available; and

(c) Socio-cultural influences.

Severity of climate will determine the level of conservation and the detail design and size of elements.

8. Mass provides heat storage to carry over daytime solar gains into evening hours. There is normally ample mass in buildings of adobe, brick, concrete block or rock construction; however, a few adjustments in the use of such materials will result in the greatest heat-storage effectiveness (such as using north/south partition walls between direct gain spaces).

Types of Passive Heating

9. The three passive solar strategies of primary importance are direct gain, thermal storage wall and sunspaces.

(a) Direct gain is simply the use of windows on the equatorial side of the building. Direct-gain glazing area should be limited to no more than 10 per cent of the floor area of the building to prevent excessive temperature swings, degradation of materials within the building by ultraviolet light, and glare. In mild climates, this may be a sufficient passive solar glazing area to meet heating requirements. Equatorial-facing clerestories can also be use for direct gain and are particularly effective for daylighting.

(b) Thermal Storage walls (either Trombe walls or water walls) can be used to balance heat delivery into the building. If the building is already of massive construction, a Trombe wall can quite easily be built simply by painting or staining the outside of the wall a dark colour and glazing over it, and the incremental cost of such a modification is relatively small. It is generally not necessary or appropriate to cut thermocirculation vents through the wall. In severe winter climates, double glazing should be used, but in mild winter climates one sheet of glazing is usually sufficient. Another option is to utilize water in containers for thermal storage (a water wall), if suitable containers can be obtained at low cost. Containers should be painted a dark colour on the side facing the window but can be any colour on the room side.

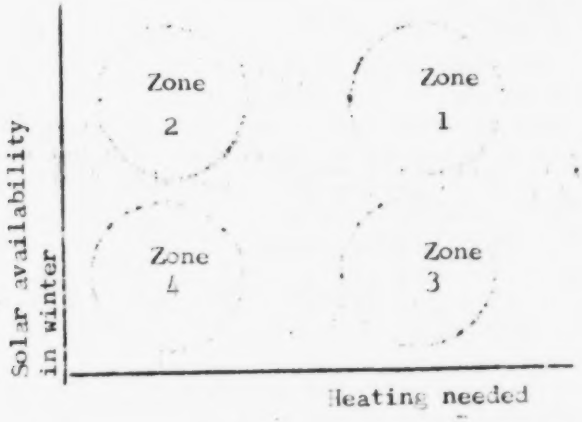
(c) An attached sunspace consists of a direct-gain room placed on the equatorial side of the building, separated from the main living or working area of the building by a wall with openings that can be closed, such as doorways or windows. The sunspace has a large area of solar glazing compared with its heat-storing mass, and, thus temperature swings will typically be large (10°-20°C). During the day, warm air is transferred from the sunspace to the rest of the building, primarily by convenction of warm air through the connecting doors and windows which are left open during the day and closed at night. The temperature in the sunspace will drop somewhat below room temperature at night but remain well above outside temperatures.

(d) An atrium within a building has proven to be a very successful passive solar design element. Properly designed, an atrium can provide passive solar winter heating, daylighting and passive summer cooling within a building, and it can, at the same time, serve as a useful living, working or public area. Such atria are most frequently included in the design of passive commercial buildings, but they have also been successfully used in several residential buildings.

Climatic Analysis for Passive Solar Heating

10. The design of passive solar heating systems depends both on the winter heating needed and the solar energy available during the heating season. The diagram below identifies four general zones according to these conditions. The heating needed increases as the outside temperature decreases, as the length of the heating season increases and as the inside temperature desired by the building occupants increases. Solar availability in winter decreases as cloudiness increases and as latitude increases.

Effectiveness of Passive Heating



The need for conservation strategies of insulation and reduced infiltration can be rank-ordered according to zone as follows:

Greatest need	Zone 3
	Zone 1
	Zone 4
Least need	Zone 2

The need for summer sun protection is usually greatest in zone 2 and least in zone 3 although this vary from case to case.

11. Characteristics of the four zones are:

Zone 1: passive heating effectiveness is greatest in zone 1, and the added investment which can be justified for double glazing, movable insulation or selective surfaces to achieve high performance is greatest.

Zone 2: Passive heating is very easy in this zone, and the size of system needed is generally modest. However, it is frequently the case that locations having a zone 2 winter climate also have a hot summer climate, and the passive heating system must be carefully designed to avoid potential adverse effects in summer. This usually means that the passive heating apertures must be carefully shaded in summer and, in extreme cases, should be completely covered to prevent diffuse solar gains.

Zone 3: Passive solar heating is difficult in climates having cold, cloudy winters. Where the heating season is very long, the energy savings are often greatest in the spring and autumn months, in which case passive heating can usually be justified. However, strategies for reducing heat loss from the passive system such as double glazing, movable insulation and selective surface, are generally necessary.

Zone 4: The incentive for passive heating is lowest in zone 4. The degree to which passive heating is taken into account in the design should usually be limited to items of low cost, for example, relocating windows to the equatorially-facing facade and using appropriate building shape and orientation.

Natural cooling systems

12. Maintaining comfort in the summer is a problem in many developing countries. Although this can be achieved with sufficient cooling of the building, the first strategy should always be to avoid cooling loads to the extent practical. In many cases, buildings become overheated inside even though outside conditions are comfortable.

13. Environmental cooling loads are caused by several factors - sunshining through windows or on the outside of roof or walls, hot outside air entering the building, or heat conducted from hot outside air to the inside. Cooling loads caused by solar gain are usually the largest problem, but these can usually be avoided through good design. Shading of the windows from direct sun is essential, especially on east and west facades, and protection from diffuse sun and reflected sun is also important. Solar loads conducted through walls and roof can be largely avoided by using white or light colours on the exterior and by insulation. Shading by vegetation is particularly effective, because the building and surrounding ground are both shaded, and the surrounding air is cooled by transpiration. The state of the art in cooling-load avoidance is well developed but unfortunately is not effectively practised in many countries.

14. Several natural sources can be used to provide cooling energy in buildings, such as the following:

(a) The night air: convective cooling;

(b) The upper atmosphere: radiant-cooling to night sky;

(c) Water evaporation: evaporative cooling;

(d) Earth cooling: storage in the sub-surface soil.

Combination of the various cooling sources is possible, e.g. initial cooling of the outdoor air by longwave radiation before using it for convective cooling.

(a) Convective cooling

15. Convective cooling implies cooling the structural mass of the building at night and utilizing the cooled mass during the following day as a sink, to absorb heat penetrating into or generated inside the building. Daytime interior ventilation is kept deliberately as low as possible to avoid bringing in hot air. In order to secure effective convective cooling, the envelope of the building should be well insulated (average value of U below about 0.67 W/m^2C) have sufficient mass "protected" by the insulated envelope and have a large surface area in relation to its mass. This method could lower the daytime inside temperature by 2-4 C. While this is a proven technique, it is necessary that the required building design characteristics are achieved.

(b) Radiant nocturnal cooling

16. Cooling of the building by the outgoing longwave radiation during the night can be achieved by either direct nocturnal cooling of the mass of the roof and subsequent protection of the upper surface by daytime external insulation or use of a specialized radiator, usually made of a metallic plate, above insulation with an air space between them. The former method can provide effective cooling in almost all climates in humid cloudy regions, but until effective and practical movable insulation becomes available, the use of this technique will be limited. The simplest design for a specialized radiator is to insulate the roof and cover the insulation with metallic sheets over an airspace of about 5 cm. Using this system, the night temperature can be dropped 4-6 C below the ambient. Any flat roof or a sloping roof with a slope up to about 30° can be transformed into a nocturnal radiator, but the experimental experience so far is only with test cells, and no actual buildings have been built using this system.

(c) Evaporative cooling

17. Cooling of buildings by water evaporation can be direct or indirect and active or passive. Inexpensive passive evaporative cooling can be provided, utilizing natural air flow by wind force through windows, by installing moist elements, such as permeable water jars or wetted matrics, in openings. It can also be provided by shaded roof ponds in direct thermal contact with the roof. Indirect evaporative cooling can be effective in regions where the summer average wet bulb temperature is below about 20 C. While research has demonstrated

the potential of shaded roof ponds to serve as a cooling system in arid regions, no field experience is available.

(d) Earth cooling

18. It is possible to lower the earth temperature, within a confined area, well below its "natural" level, by eliminating its heating by the sun while encouraging evaporation from the earth surface. This can be done by raising the building off the ground and supporting evaporation from the surface by irrigation or feeding rains below the buildings. Alternatively, the soil can be covered with a layer of gravel, at least 10 cm. thick and, in regions with dry summers, irrigating it. Using this technique, the difference between the outdoor maximum temperature and the cooled earth temperature can be up to 15 C (in mid-summer), providing a good heat sink for the building. In this area, too, no research on the performance of practical building systems seems to have been done.

19. In view of the fact that very large populations in the developing areas in hot dry regions and in hot humid conditions have to suffer serious discomfort for considerable periods of the year, the search for low-cost cooling is a key area where new basic concepts and designs are badly needed. As materials are critical to effective progress, promoting use of local materials, both for passive solar heating and natural cooling systems, will require considerable research and development effort. Research is needed into glazing materials, insulating materials using agricultural and industrial residues and wastes, cost-effective selective coating materials and their associated manufacturing processes, corrosion and weather resistance of materials, and reliability of components.

20. In order to carry out the above research tasks, and developmental minimal meteorological data should become available. Special manuals should be disseminated to guide the preparation of national and regional bioclimatic design handbooks. A systematic programme for the construction of demonstration buildings should be undertaken as an important step in the dissemination of information from one part of the world to another.

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ENERGY PLANNING IN THE GAMBIA

BY

OUSMAN JAMMEH, SENIOR PLANNER

NOVEMBER 1984

I. INTRODUCTION

In a global context, the factor, ENERGY reached a crisis point in the early seventies when oil producing countries shot up the prices of crude oil. The direct consequence of this is a very steep rise in production costs. From this point on the various countries of the world, at different levels of economic development and factor endowments began the process of adjustments to this reality. This adjustment entails:

(a) Increasing the efficiency of energy use through rational pricing, the use of incentives and various demand management measures;

(b) undertaking an expanded and more diversified programme of investments to develop indigenous energy resources which will be cheaper than imported energy;

(c) reorienting industrial, agricultural and transport development strategies to take account of the higher costs of energy inputs; and

(d) strengthening institutional and management capabilities in the energy sector to design and carry out these tasks effectively.

These measures are particularly difficult for the oil importing developing countries, such as The Gambia, who must raise the finance for them while continuing to pay for oil imports until the measures are completed and the necessary investments mature.

In the case of The Gambia petroleum products do not constitute the major share of the total energy needs but are an important energy input in the operations of public utilities (water and electricity), the small industrial sector, the transport and communications sector and to a lesser degree the agricultural sector. The bulk of the population, particularly the rural majority continue to derive a large proportion of their energy consumption needs from fuelwood and the use of animal traction. However this alternative source of energy is faced with the serious problem of depletion through over-exploitation, bushfires and increased farming and grazing. This situation makes the petroleum-associated energy crisis assume greater dimensions.

Energy demand comes from two main subsectors: traditional and commercial. About 75 per cent of total firewood consumption is by rural households, and the remaining 25 per cent by urban households. Almost all petroleum products are used in electricity generation and in the transport sector. Table 1 has the breakdown by sector for 1980.

Table 1. Consumption of oil products by sector (1980)

Sector	Consumption (m^3)
Agriculture	3,730
Industry	7,430
Public Utilities	9,180
Transport	31,920
Domestic/Tertiary	7,230
Total	59,490

Source: Second Five Year Plan, P. 126.

The Gambia's energy endowment is modest. The country is very flat with a maximum elevation of 40 metres above sea level, which precludes major hydroelectric potential. However, sub-regional co-operation within the context of OMVG (The Development of The Gambia River Basin) open up opportunities for hydroelectric power from dams to be constructed on upper parts of The Gambia River Basin. There also exists some energy potential for wind, solar and biomass but these are presently grossly under exploited. Exploitation of these renewable sources of energy demand huge financial outlays which The Gambia can hardly afford in the absence of external financing.

II. BROAD POLICY FRAMEWORK FOR ENERGY PLANNING

A. THE CONSTRAINTS

As indicated earlier on, the fundamental energy constraints facing The Gambia are:

1. Increasing oil import bills and their attendant crippling effect on national balance of payments;

2. deforestration - limiting the scope of fuelwood resources and the introduction of desert-like conditions;

3. financial constraint - restricting the research and development of the alternative renewable sources of energy;

4. the relatively small quantities required by The Gambia creates a supply problem. Suppliers are usually nor attracted by small orders and furthermore The Gambia does not enjoy the benefits of economics of scale.

In addition to the above main problems there are also other limitations such as manpower constraints, inadequate investment and insufficient co-ordination and planning among relevant government agencies, and paucity of basic data.

As an initial planning step to resolve these problems, an Energy Survey and Master Plan was drawn. This has defined an investment programme for resource development, energy conservation, pricing and taxation.

B. DEVELOPMENT OBJECTIVES

The Gambia's Second Five Year Plan 1981/82 - 1985/86 states the following objectives for the energy sector:

1. To achieve efficient and judicious consumption of energy;

2. to provide adequate and secure domestic and imported energy supplies for present and projected needs;

3. to minimize the cost of energy to the economy, through reducing energy imports and increasing efficiency of investment;

4. to ensure that the above objectives are met in an environmentally acceptable fashion.

C. DEVELOPMENT STRATEGY

Pursuant to the above objectives, the Plan also put forward the following strategy:

1. To encourage conservation by domestic, commercial, and institutional consumers;

2. to accelerate feasibility studies for the development of renewable energy resources;

3. to continue exploration for oil and other fossil fuels;

4. to reduce the unit cost of electricity production by using heavy fuel oil and upgrading the transmission system;

5. to provide limited expansion of generating capacity in the rural areas;

6. to introduce solar water heaters into households, hotels, and factories using large amounts of low temperature heat;

7. to promote use of energy saving vehicles, through appropriate fiscal policies and government regulations.

III. THE PLANNING PROCESS - INSTITUTIONAL ASPECTS

As the apex of the various institutions concerned with energy is the National Energy Commission (NEC) chaired by the Honourable Minister of Economic Planning and Industrial Development with other members comprising senior executives and experts from the public and private sectors. The Commission will be the principal advisory body to the Cabinet on energy issues.

An Energy Planning Unit (EPU) has been established within the Ministry of Economic Planning and Industrial Development to serve as the Secretariat of the NEC. This unit is charged with the responsibility of preparing detailed policies and programmes on energy development and conservation within the framework of the long-term Energy Master Plan and the National Development Objectives. The unit is also expected to build up a sound data base for energy planning. In order to ensure the successful implementation of energy policies and programmes, an evaluation and monitoring system within the EPU is devised. It focuses on energy conservation, pricing and resource exploitation.

The Ministry of Economic Planning collaborates with relevant ministries and departments in formulating a publicity programme on energy matters to encourage conservation of energy.

IV. PROJECTS AND PROGRAMMES

Training: An energy training programme is vigorously pursued for personnel in energy-related agencies, particularly the Gambia Utilities Corporation.

Forestry: A number of forestry development programmes, covering research, institutional strengthening and afforestation, are currently being implemented within the framework of the Second Plan.

Energy conservation: The Gambia Public Transport Corporation will always endeavour to use more fuel efficient buses. The feasibility of operating minibuses for intercity transportation is subject to further consideration. New and improved fuelwood cooking stoves continue to be produced and research into further improvement in the efficiency of these stoves is in progress.

Renewable energy resources: Assistance has been obtained from the Regional Centre for Solar Energy (CRES), Bamako, Mali, for the establishment of a national centre for renewable energy (RE) in The Gambia. This centre will carry out research and limited production within the field of RE. The Gambia Technical Training Institute is being considered as a possible candidate for such a centre. The Departments of Water Resources and Community Development are carrying out some research in RE and have implemented or are implementing projects and programmes concerning solar water heaters, solar fish driers, solar pumps, wind pumps and biomass production but on a very limited scale.

Pricing Policy: As stated in Second National Development Plan, the pricing policy will be used to achieve development objectives and to complement other measures. Prices of petroleum products will be reviewed periodically, keeping in view international prices and the revenue and balance of payments of The Gambia.

V. CONCLUSION

To some extent The Gambia can attain the laudable objectives set in the Development Plan for the energy sector with proper and effective planning, implementation and monitoring. There will be limitations. The various constraints identified will reduce the capacity of attaining the national goals and objectives. Furthermore, it ought to be realised that The Gambia is a small country within a much wider community of nations and that the subject of energy is very closely related to the phenomenon of environment. Environmental factors do not respect political boundaries. Therefore, for a more effective control over our energy resources, the planning, implementation and monitoring will, of necessity, transcend the national level and extend to both the regional and inter-regional levels.

OIL PRODUCTS IMPORTS RELATIVE TO TOTAL IMPORTS AND DOMESTIC EXPORTS, 1974/75 - 1979/80

	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80
Total imports (million Dalasi)	88.3	144.3	159.8	208.1	221.0	290.4
Imports of petroleum products (million Dalasi)	7.9	9.1	11.3	19.4	21.0	26.2
Petroleum imports as a percentage of total imports	8.9	6.3	7.7	9.3	9.5	9.0
Total domestic exports (Million Dalasi)	83.4	75.0	104.6	74.4	69.4	64.8
Percentage by which petroleum imports exceed total domestic exports	9.5	12.1	10.8	28.1	30.3	40.4

Source: Second Five Year Plan, I. 129.